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TENSILE STRENGTHS OF PROBLEMS SHALES AND CLAYS

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TENSILE STRENGTHS OF PROBLEM SHALES AND CLAYS

by

FRANCIS J. RECHNER, BE

THESIS

Presented to the Faculty of the Graduate School of
The University of Texas at Austin
In Partial Fulfillment
of the Requirements
for the Degree of

MASTER OF SCIENCE IN ENGINEERING

THE UNIVERSITY OF TEXAS AT AUSTIN

MAY 1990

ABSTRACT

THE TENSILE STRENGTHS OF PROBLEM SHALES AND CLAYS

BY

CAPTAIN FRANCIS J. RECHNER, USAF

in partial fulfillment of the requirements of

Master of Science in Petroleum Engineering

The University of Texas at Austin

May 1990

109 Pages

The greatest single expense faced by oil companies involved in the exploration for crude oil is that of drilling wells. The most abundant rock drilled is shale. Some of these shales cause wellbore stability problems during the drilling process. These can range from slow rate of penetration and high torque up to stuck pipe and hole abandonment. The mechanical integrity of the shale must be known when the shales are subjected to drilling fluids to develop an effective drilling plan.

Air, demineralized water, 5% potassium chloride (by weigth KCl) and 10% KCl solutions were used as typical drilling fluids on a series of six samples. The tensile

strength of each shale was measured via the Brazilian method and used as a measure of the mechanical integrity. Native and reconstituted samples were tested. In general, (1) KCl increased the tensile strength of shales, while demineralized water decreased the strength, (2) There is little or no correlation between tensile strengths obtained on reconstituted and intact rock samples and (3) the effect of confining pressure was merely an additive effect on the tensile strength.

To my loving and devoted wife, Daphne

ACKNOWLEDGMENTS

No one ever accomplishes anything without the aid of others. My wife, Daphne, has been extremely supportive during the past two years while this work was performed. Without her encouragement this work would not have been completed. My parents, Frank and Helen Rechner, instilled the necessary pride, determination and faith in me to overcome any obstacle in life. Their exemplary life will not be forgotten. My in-laws have also been very supportive.

I thank Dr. K. E. Gray for allowing me to work on this project and for his guidance when the "light at the end of the tunnel" was a train. I also thank Dr. J. T. Holder for his comments as the additional reader for the thesis. The many discussions with both of these gentlemen were extremely helpful throughout the project.

The technicians at CESE were simply outstanding. My thanks and servitude to Preston Mewhinney for the never ending machine work; Charles Stephenson for coring and sample preparation, and Steven Williams for the computer hardware and mediation.

Francis J. Rechner
May 1990

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CHAPTER ONE
LITERATURE REVIEW

1.1 Introduction

Although the amount of drilling has been on the decline for the past several years in the United States, the problems associated with the drilling process have not diminished. Wells are being drilled deeper or horizontally to find the ever decreasing quantities of oil and gas stored in the earth. One of the most common troublesome rocks drilled is shale. Shales are formed over geologic time in low energy environments, such as marine basins and lakes. They are composed of silt and clay size particles. Shales cause over 90 percent of wellbore stability problems.[19] Some of the problems caused by wellbore stability are stuck pipe, slow rate of penetration (or no penetration at all), high torque, drag, bridging, poor directional control, washouts, high mud and cementing costs, poor log interpretation and/or failure to obtain logs.[17]

1.2 Clays

Clay minerals are present in troublesome shales. The most unstable clay is smectite, known as montmorillonite when the ionic substitution for the Al^{3+} ion is minimal. This is followed by mixed-layered or inter-

layered clays (a combination of smectite and illite), illite, chlorite and kaolinite.[2,18] Montmorillonite has an alumina octahedral sheet surrounded by two tetrahedral sheets. The structure is represented by the chemical formula $4SiO_2 Al_2O_3 H_2O$ + water, with some Mg^{2+} or Fe^{2+} replacing the Al^{3+} ion.[2,18] This substitution causes an overall negative charge on the lattice.

Illite, like smectite, has an octahedral layer and substitution takes place. Aluminum cations (Al^{3+}) substitute for silica cations (Si^{4+}) in the tetrahedral. Again, this yields a strong negatively-charged surface. The mixed layer clays are a combination of the illite and montmorillonite structures.

The negative charges are balanced by positive cations. When the balancing cation is potassium (K^+), the layers are held tightly together and water can not invade the lattice structure and cause swelling and instability. However, when the balancing cations are sodium (Na^+) or calcium (Ca^+), the structures are not held as tightly together,and water can invade causing swelling and instability.[2,18]

1.3 Hydration and Swelling

According to van Olphen[20] and Steiger[18], there are two principle mechanisms for swelling in clays. The first is surface hydration, representing only a small amount of water. There is little visible loss of strength or swelling. The second is osmotic swelling which involves larger volumes of water, hence causing more expansion than in the first case.

1.4 Tensile Strength Testing

Many experimental methods exist for testing the strength of materials and many theories of failure describe these tests. Rocks often fail in compression during the drilling process, but with an open wellbore, caving, heaving and sloughing will occur when the rocks fail in tension. The tensile strength is one of the most difficult material properties to determine in rocks. Several of the tensile strength methods are described below.

The classic method to determine the tensile strength is the direct-pull test.[10] This works well in metals and reinforced concrete, but has several disadvantages for rock materials. First, the applied tensile load must be uniformly applied over the end of the specimen, and second, the

grips must minimize lateral stresses in the specimen. Usually the second concern is eliminated by machining the center section of the sample to a smaller diameter than the remainder of the sample. However, this is a complicated process for rocks and shales that may contain well developed microfractures. Even small surface scratches reduce the tensile strength. Additionally, cracks, weakness planes and other mechanical defects are contained in rocks, further reducing the tensile strength. Some investigators[10,12] have altered the method of holding the specimens. Epoxy cement has been used to secure the end caps while flexible cables, ball and socket joints have been used to apply the tensile load.

In addition to the direct pull test, several indirect methods exist. The bending method requires a sizable sample to be supported by two points underneath the specimen, while the load is applied from above. The loading point is equidistant from the supporting points. This causes bending moments with one surface in tension and the opposite in compression.

Another indirect tensile strength test is the Brazilian method. This method was presented by Carneiro and Akozawa[10]. In this test, a right circular disk is diametrically compressed between two pistons (platens). This method has the advantage over the bending method in that it requires a sample of smaller size. This lessens the chance of encountering the

mechanical defects mentioned above. For an elastic material in the Brazilian test configuration, a constant tensile stress is produced along the diameter perpendicular to the applied load.[8] At failure, the tensile strength is given by:

$$T = (2F) / (\Pi t D) \qquad (1)$$

where:

T = tensile strength at failure (psi)

F = Applied load (lbs)

t = Thickness of Disk (in)

D = Diameter of Disk (in)

Unfortunately, this type of loading produces high shear stresses adjacent to the loading platens causing premature sample failure, local crushing along the load line and inconsistent tensile strength values.[8,10] By inserting padding material, such as a piece of cardboard, between the platens and the sample, more consistent tensile strengths are produced. This has been labeled "strip" loading.[8] Figure 1 shows a Brazilian test sample under strip loading. This type of loading reduces the compressive and shear stresses near the loading area and averts premature shear failure. Hondros[6] analyzed this "strip" loading and deduced for small values

of p (from Figure 1), the tensile strength is the same as stated in equation 1. Figure 2 shows the stress distribution derived by Hondros.

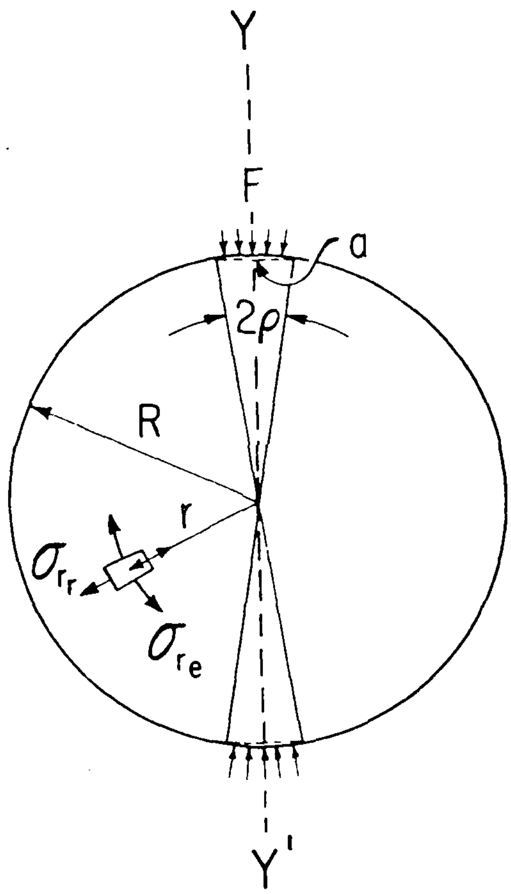


Figure 1: Brazilian Test Sample under Strip Loading[8]

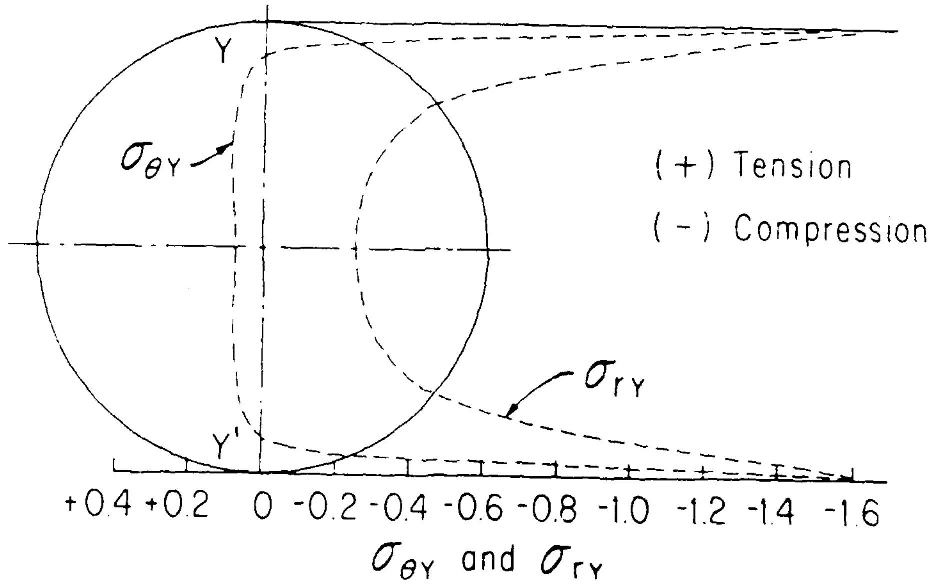


Figure 2: Stress Distribution of Brazilian Test Sample[6]

1.5 Problem Statement

The majority of previous efforts to determine the mechanical properties of shales has been performed on reconstituted material. For this study, the Brazilian tensile test was performed on intact and reconstituted shales and clays in an effort to determine the relationship between intact and reconstituted material. This study also attempts to relate the results of this test to other experiments performed at the Center for Earth Sciences and Engineering (CESE).

These other experiments include:

1. Atterberg Limits Test
2. Capillary Suction Time Test
3. Ensilin Test
4. Methylene Blue Capacity
5. Specific Surface Area Test
6. X-Ray Diffraction Analysis

Finally, this study compares the tensile strengths of both the reconstituted and intact samples when formed in the presence of varying concentrations of a potassium chloride solution.

CHAPTER TWO
EXPERIMENTAL METHODS

2.1 Experimental Apparatus

The following equipment was used to perform the tensile testing experiments.

1. Brazilian Apparatus
2. Soil Test Machine
3. Hewlett-Packard XY Recorder
4. Coring System
5. Ball and Hammer mill
6. Ro-Tap Testing Sieve Shaker
7. Tyler sieve size 200
8. Balance (0.0001 gr accuracy)
9. Drying Oven
10. Glassware for fluid solutions
11. Sample Fabrication Cells
12. Load Frame
13. Lathe
14. Mortar and Pestle

Figures 3 and 4 show schematic diagrams of the Brazilian test apparatus. Figure 3 depicts the apparatus used for atmospheric confining pressure, while Figure 4 represents the system used for elevated confining pressures. All equipment was available from the Center from Earth Sciences and Engineering. The major pieces of equipment are described below.

2.1.1 Brazilian Test Device (BTD)

The BTD consists of a finely-machined case with removable top and bottom platens. The platens have elevated load strips with a curvature radius of 0.5" The BTD is centered in between the upper platen of the soil test machine and the transducer (described below).

2.1.2 Soil Test Machine

A 30,000 pound Soil Test Machine was used to apply the force to fail the sample.

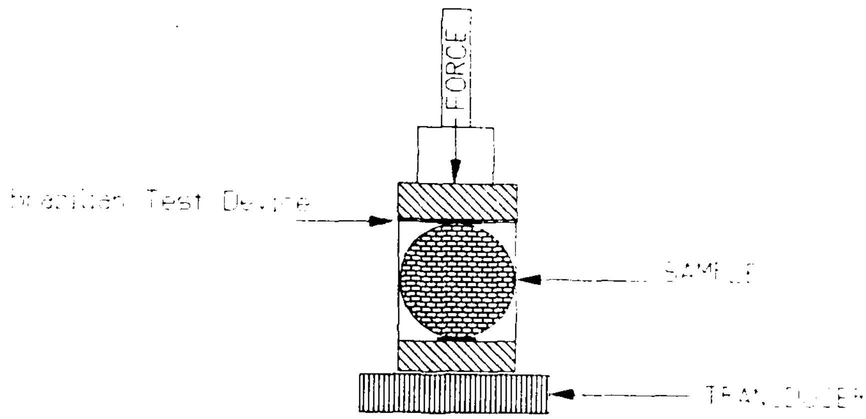


Figure 3: Atmospheric Confining Pressure Apparatus

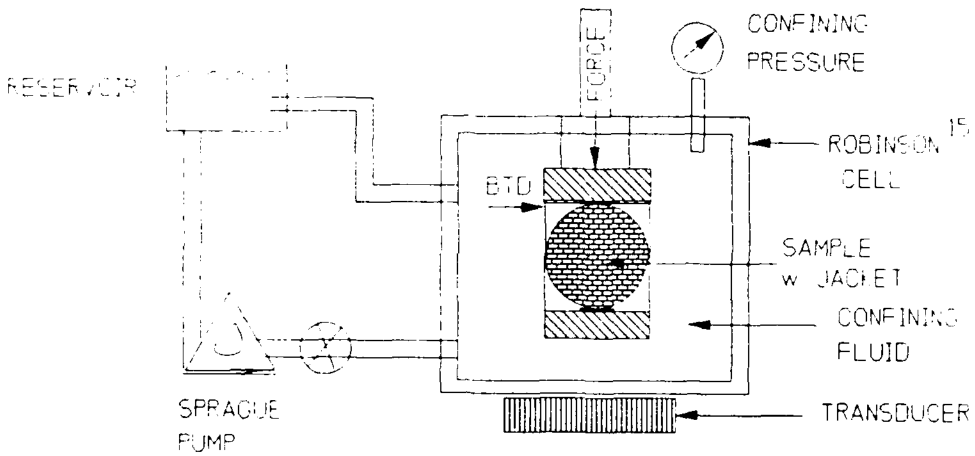


Figure 4: Elevated Pressure Experimental Apparatus

2.1.3 Transducer

The transducer converted the load applied from the soil test machine into an electrical signal sent to the chart recorder.

2.1.4 Chart Recorder

The Hewlett-Packard 7046B XY Recorder was used to yield a graph of applied load versus time.

2.2 EXPERIMENTAL TECHNIQUE

2.2.1 Sample Preparation

The shale samples were obtained from core samples provided by Phillips Petroleum Company and Texaco Incorporated. Gold Seal Bentonite, obtained from NL Baroid Incorporated, was used a standard clay.

2.2.1.1 Reconstituted Samples

The core samples were broken down to gravel size pieces using a mortar and pestle, then ground using a ball and mill grinder. The result-

ing fines were sieved through an U.S. Standard Sieve 200 mesh using the Ro-Tap Testing Sieve Shaker and dried at 100^{o} C for not less than 12 hours in a drying oven. Twelve grams of the shale were added to the desired fluid, placed in the fabrication cell and compacted under 12,500 psi for not less than 12 hours. The sample was removed from the fabrication cell, weighed and measured.

2.2.1.2 Native Samples

The native core samples were cored using a one inch core barrel and kerosene as the drilling fluid. Cylindrical cores approximately four inches in length were obtained in this manner. These were then cut and machined to right cylindrical discs (wafers). After machining; the weight, thickness and diameter of the wafer was recorded. Only Texaco's Atoka and Pierre shales provided intact samples.

2.2.2 Test Procedure

The experimental procedure for atmospheric tests and elevated confining pressure tests is essential the same, except the elevated confining pressure test requires more equipment. Both procedures are described here.

2.2.2.1 Atmospheric Tests

The weighed and measured sample was placed in the BTD, which, in turn, was placed on the transducer in the soil test machine. The alignment was such as to minimize bending moments. Load was applied to induce failure, and the load at failure was measured via the chart recorder. Following the test, the sample was then dried in a 100^{o}C oven for not less than 12 hours, weighed again and the fluid content determined.

For native Atoka shale it was necessary to weigh the sample before placement in oven due to the failure characteristics.

2.2.2.2 Elevated Confining Pressure

The weighed and measured sample was jacketed with Perma-Tex FormaGasket. It was then placed in the BTD and lowered into the Robinson[15] Cell. The system was then placed on the transducer, pressurized and checked for leaks. Load was applied to induce failure, and the failure load was measured via the chart recorder.

2.2.3 Experimental Fluids

The four test fluids used in these experiments were:

A. Air

B. Demineralized Water

C. 5% KCl in Demineralized Water (Wt Percent)

D. 10% KCl in Demineralized Water (Wt Percent)

The densities of these fluids were 0.0013, 0.9982, 1.0338, and 1.0634 g/cc, respectively.[13] These fluids were chosen based upon inputs from industrial representatives. These fluids were also used previously at CESE in the Atterberg Limits, Capillary Suction Time, Ensilin, Methylene Blue and Specific Surface Area Tests. Using the same fluid allows comparison between the sets of data.

2.2.4 Shales

Brazilian tensile tests were performed on the following shales and clays:

Gold Seal Bentonite	(GSB)
Phillips Andrews County	(PAC)
Phillips Ekofisk	(PEF)
Pierre Texaco	(PTX)
Texaco Mississippi Canyon	(TMC)
Texaco Atoka	(TXA)

CHAPTER THREE
RESULTS

Figures 5-10 graphically depict the tensile strength results for the reconstituted samples. Figures 11 and 12 depict the values for the native samples. Figures 13 and 14 compare the results for the two clays contained in figures 5-14. This shows the difference between native and reconstituted shales. Table 1 gives the composite tensile strength values for all samples tested, including those done at an elevated confining pressure.

The Brazilian tensile strength tests were carried out in the presence of four fluids; air, demineralized water, 5%KCl/H_2O and 10% KCl/H_2O solutions. For ease in terminology, the case where air is the preparation fluid is considered to be dry, that is, no external water or solution was added to either the reconstituted or native shales.

The results for the dry, reconstituted case are summarized below. Gold seal bentonite (GSB) had the highest tensile strength at 530.9 pounds per square inch (psi). This was followed by PEF with 397.8 psi, TMC at 385.8 psi, PTX at 379.2 psi, PAC at 372.9 psi and TXA at 220.4 psi. All tensile strength values listed in Table 1 are $\pm$ 12%.

Table 1: Composite Tensile Strength

Tensile Strength (psia)

Recons. Shale	Dry	D. H2O	5% KCL	10% KCL
GSB	530.9	335.6	352.8	262.4
PAC	372.9	300.3	347.8	363.5
PEF	397.8	N/A	N/A	362.8
PTX	379.6	298.3	439.8	487.2
TMC	385.8	439.6	457.5	453.2
TXA	220.4	184.2	256.7	298.0

Native Shale	Dry	D. H2O	5% KCL	10% KCL
PTX	389.2	292.9	338.5	400.8
TXA	1108.0	126.0	144.4	120.0

Confining Pressure = 1000psig

Native Shale	Dry
TXA	2296.0

With the addition of demineralized water, some expected and some unexpected results occurred. The tensile strength as a whole dropped, with the exception of TMC. For example, GSB dropped 37% to 335.6 psi, PAC dropped 19.5% to 300.3 psi, PTX fell 21.4% to 298.3 psi and TXA fell 16.4% to 184.7 psi. PEF would not fail in a brittle manner,

only plastically. This sample was run repeatedly, but no tensile strength value could be attained with demineralized water present. The surprising result for this series of tests was TMC, the tensile strength rose to 439.6 psi.

The observed tensile strengths rose when the sample was formed in the presence of the 5% KCl solution. GSB's value is now listed at 352.8 psi, an increase of 5.1% over the demineralized case. PAC had a larger increase, up 15.8% to 347.8 psi, while PEF would again only deform, and not give a true tensile strength reading. PTX exhibited the most dramatic increase, up 47% to nearly 440 psi. TMC and TXA increased 4 and 39.8 percent to 457.5 and 256.7 psi, respectively.

The results for the 10% KCl case followed the same trends as for the 5% case, with the exception of GSB. The tensile strength value for this sample dropped 26 percent to 262.4 psi. PEF failed in a brittle manner and its tensile strength was recorded at 362.8 psi. TXA increased 16 percent to 298 psi.

Figures 11 and 12 show the strength values for the native samples PTX and TXA. Care must be taken when analyzing these figures. The dry case on each graph is native intact rock. When this rock was subject-

ed to fluids, the specimen simply disintegrated. PTX formed a cloudy solution in the presence of demineralized water and all concentrations of KCl. TXA, which had a tensile strength of approximately 1100 psi, also lost all integrity when it was subjected to the test fluids. This sample disintegrated along well defined lines, sometimes breaking in half. For this reason, the native intact samples were prepared in the presence of fluid exactly like the reconstituted samples. This procedure is described in Chapter two.

Native TXA was also tested at a confining pressure of 1000 psig. The effect of the confining pressure was an additive effect. The tensile strength of native TXA was increased by the value of the confining pressure.

The differences in strength for the reconstituted and native samples are depicted in Figures 13 and 14. The PTX values are in good agreement between the native and reconstituted cases, but for TXA they do not agree for the dry case.

Figure 5. GOLD SEAL BENTONITE
Tensile Strength vs Density

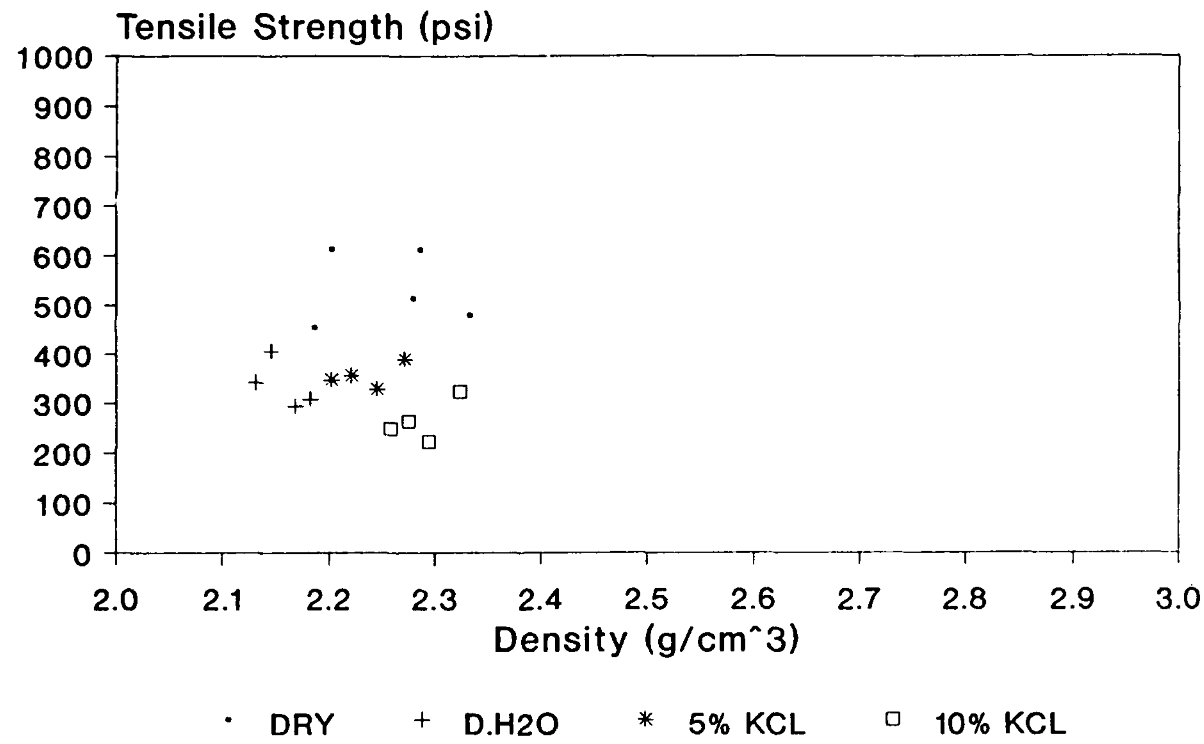


Figure 6. PHILLIPS ANDREWS COUNTY
Tensile Strength vs Density

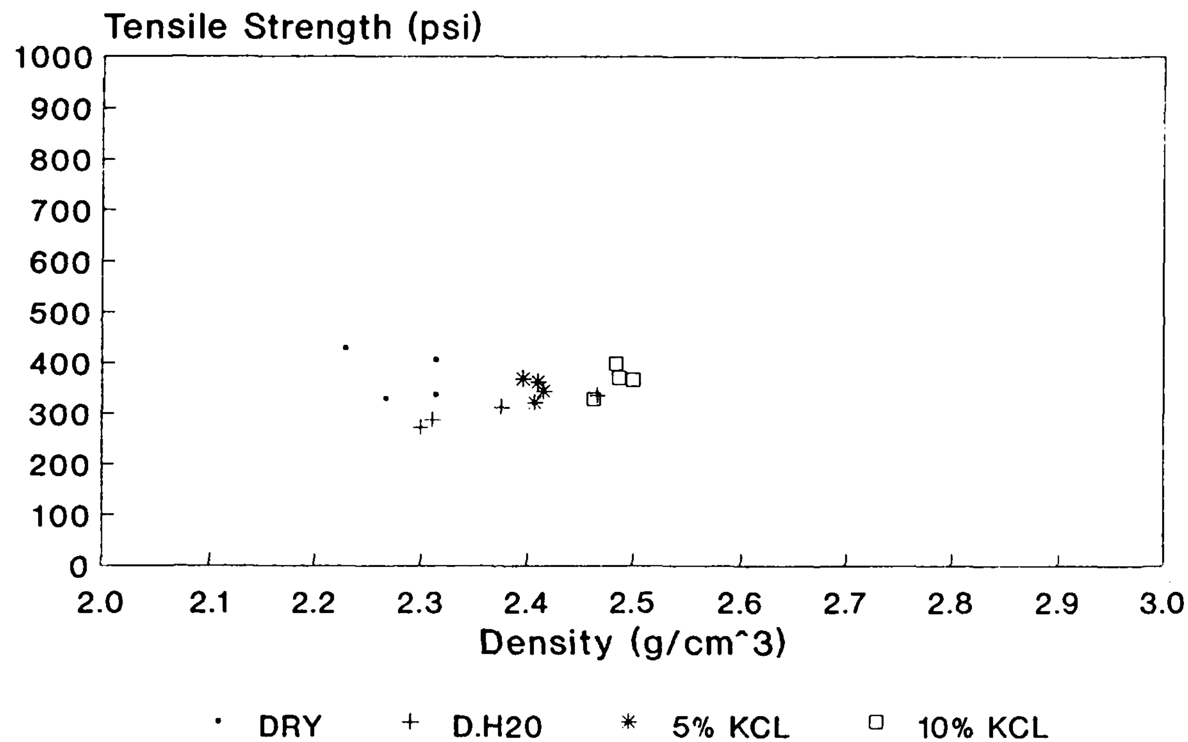


Figure 7. PHILLIPS EKOFISK
Tensile Strength vs Density

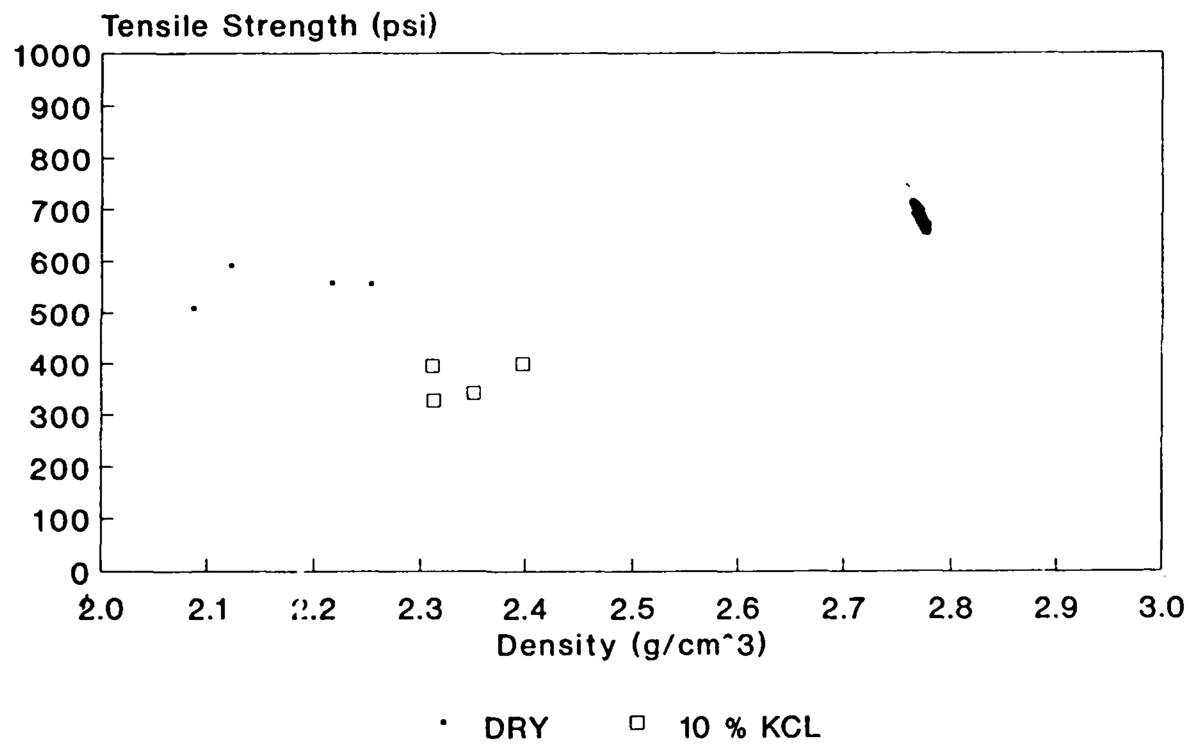


Figure 8 PIERRE TEXACO
Tensile Strength vs Density (Recons)

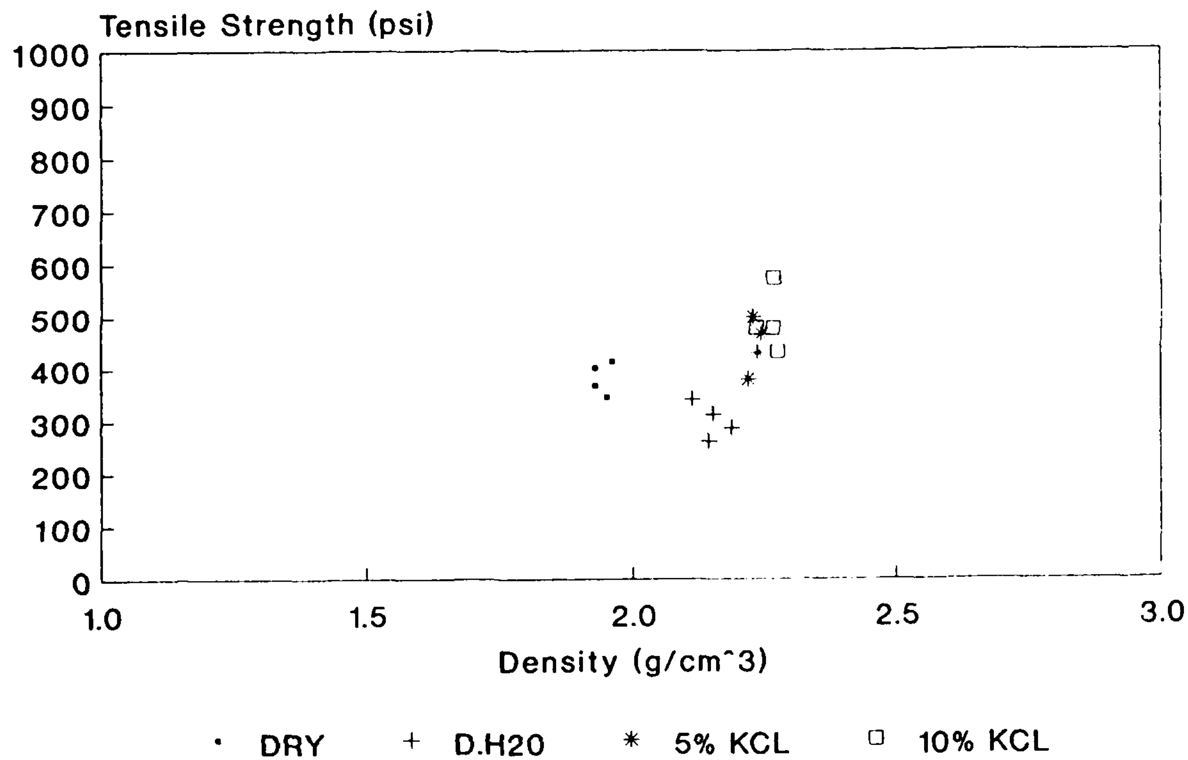


Figure 9. TEXACO MISSISSIPPI COUNTY
Tensile Strength vs Density

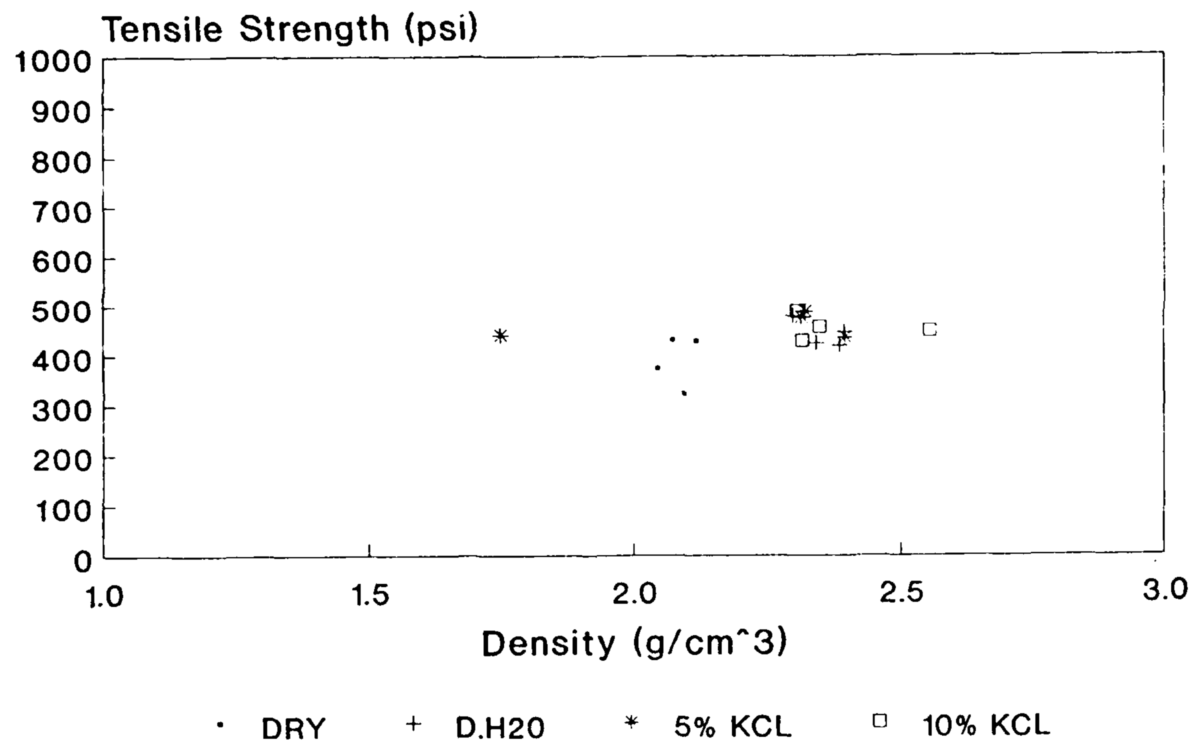


Figure 10. TEXACO ATOCA
Tensile Strength vs Density (Recon)

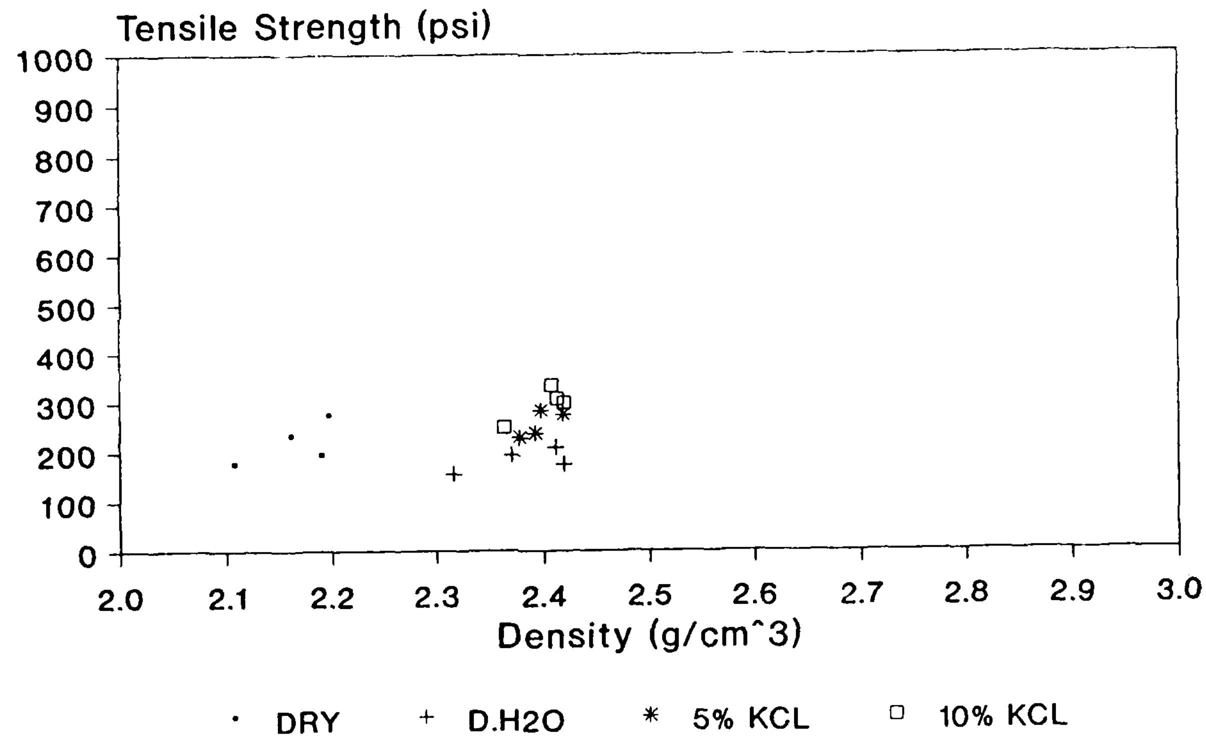


Figure 11. PIERRE TEXACO
Tensile Strength vs Density (Native)

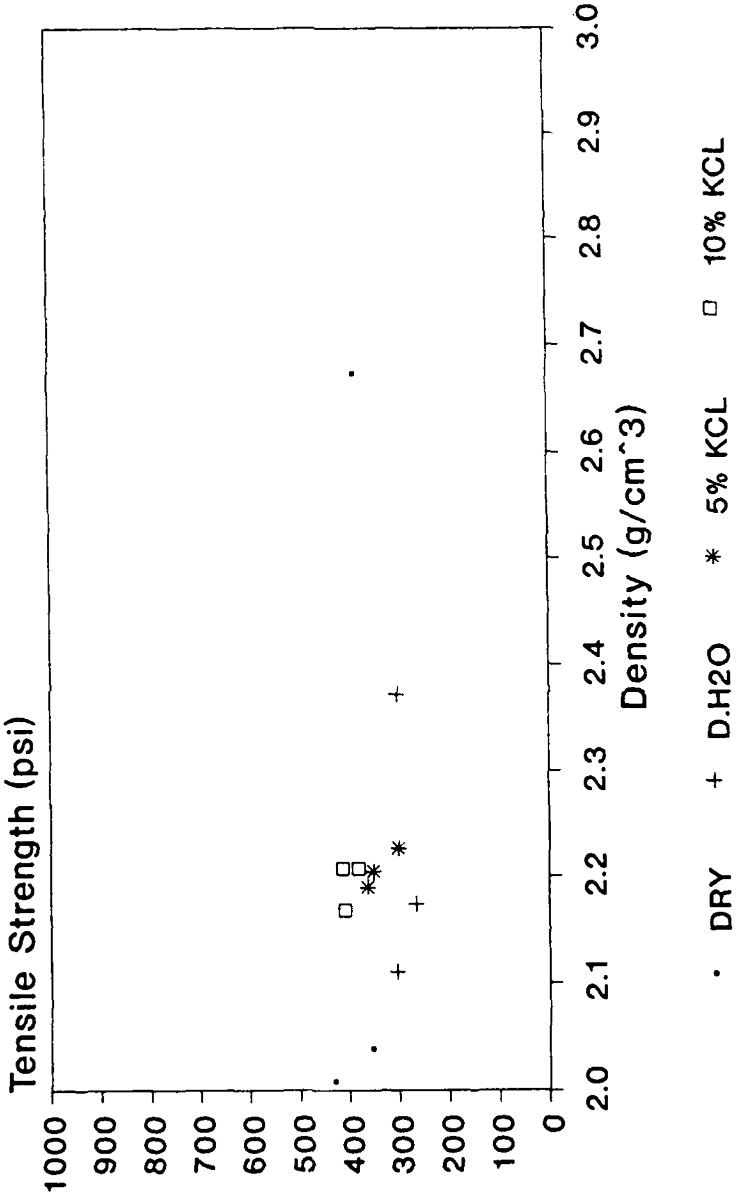


Figure 12. TEXACO ATOCA

Tensile Strength vs Density (Native)

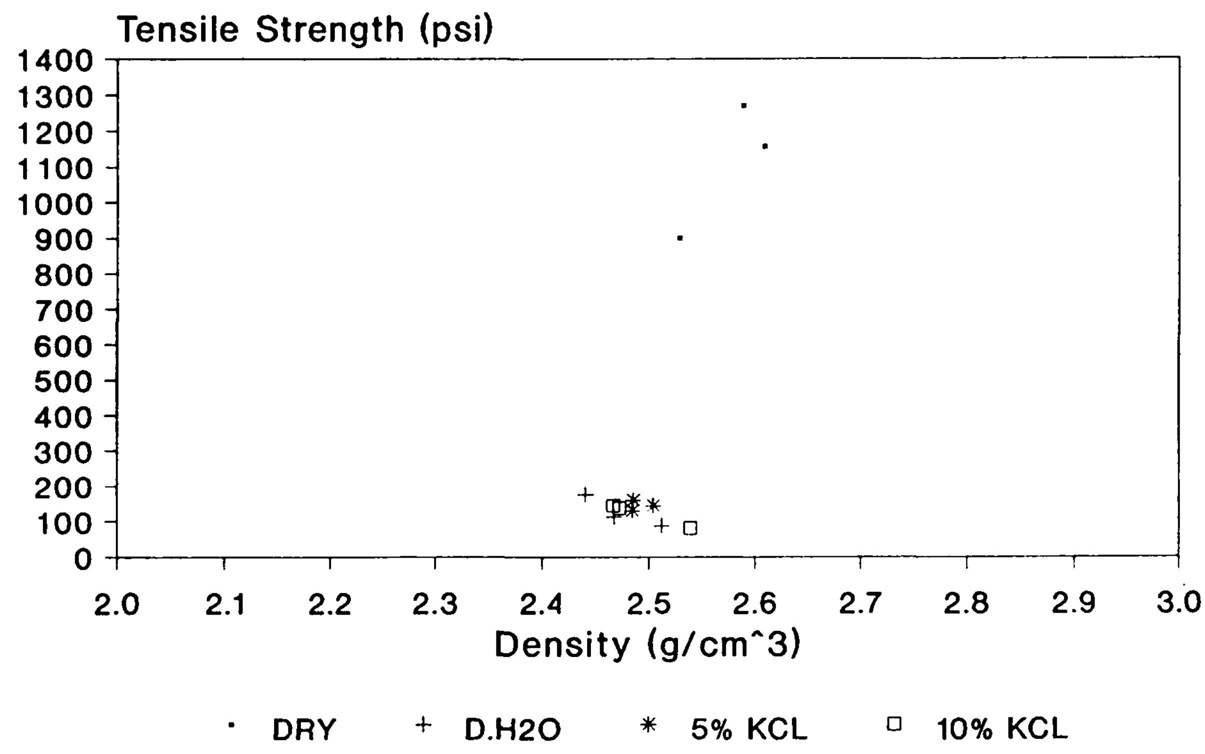


Figure 13. PIERRE TEXACO
Tensile Strength

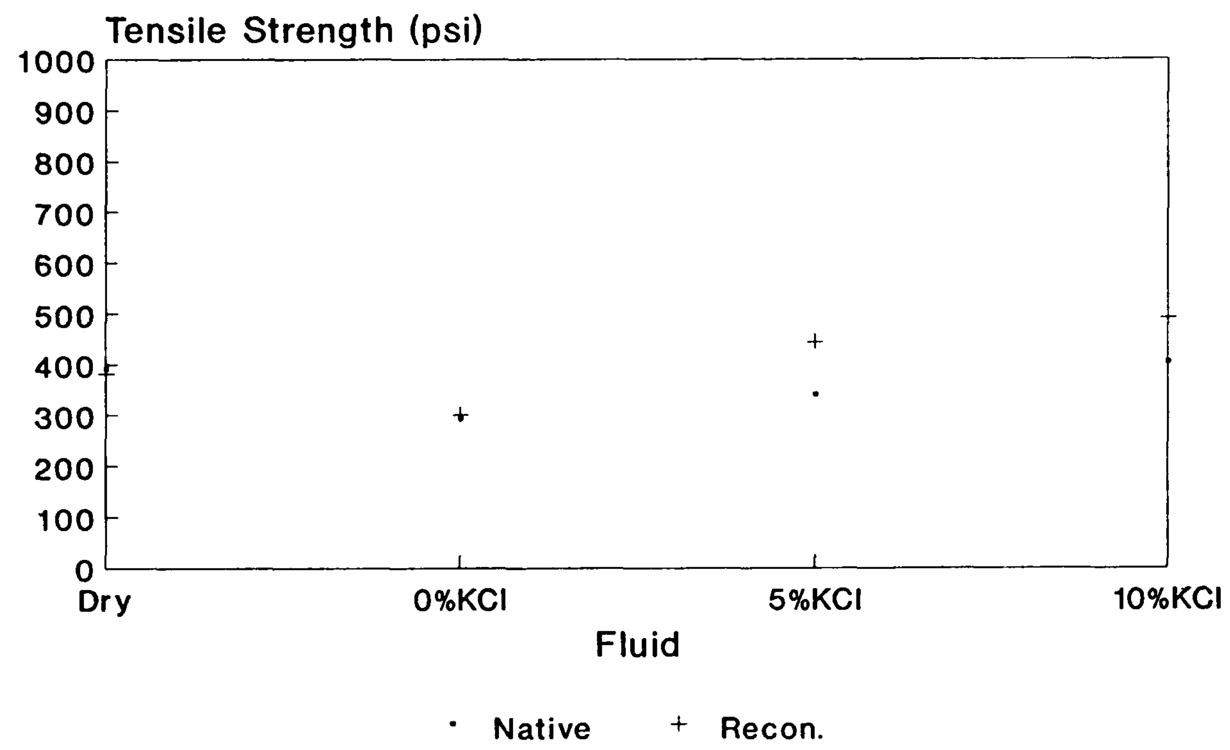
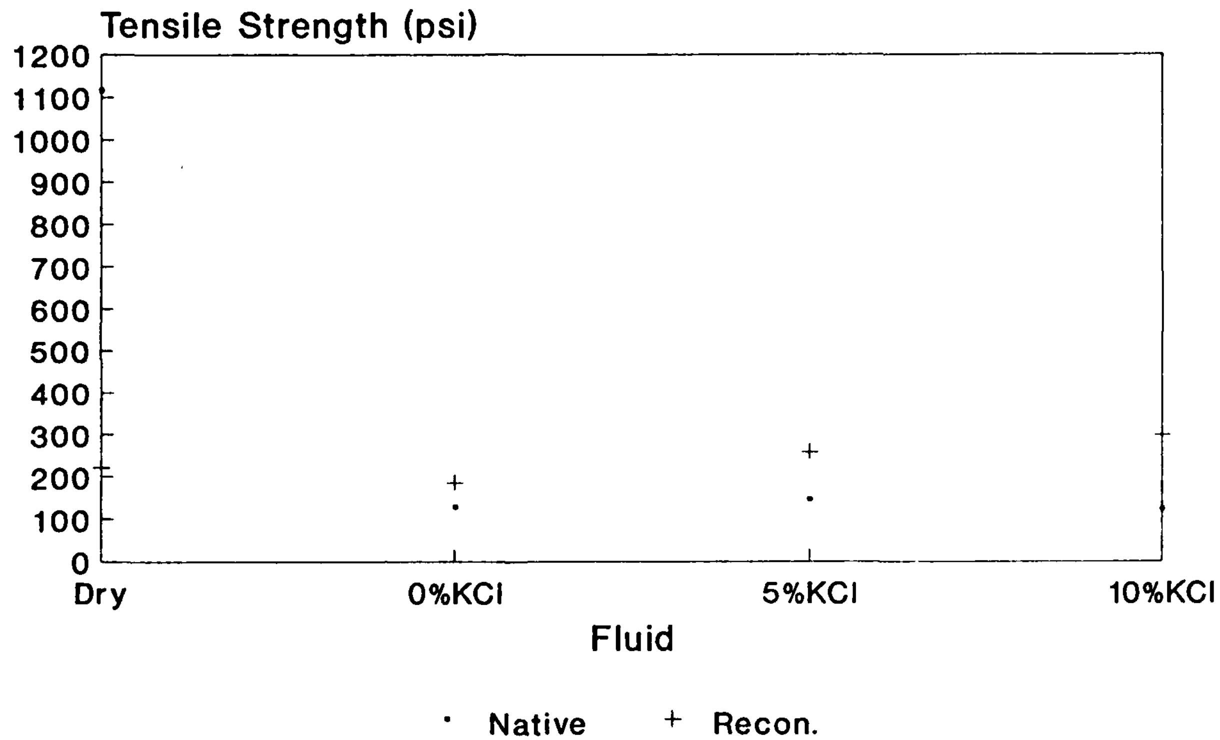


Figure 14. TEXACO ATOCA
Tensile Strength



CHAPTER FOUR
DISCUSSION

4.1 Brazilian Tensile Strength

Several researchers have shown that the results obtained from Brazilian tests may be as much as 30 percent low when compared with compressive strength to tensile strength ratios.[8] Others claim that the results will be lower than the bending test, but higher than the direct-pull method.[10,12] In any event, the relative tensile strengths observed will be consistent.

The effect of demineralized water and water containing potassium chloride was graphically shown in chapter three; demineralized water caused the tensile strength to decrease, must probably due to the hydration mechanisms discussed in the literature review. Although the samples formed in the presence of water were not as fragile and easily damaged as those formed dry, the addition of water caused an overall decrease in strength. The problems associated with hydratable clays are also well documented in the literature.

The effect of KCl, on the other hand, was to strengthen the rock. In the drilling process, this translates to longer exposure times before well-

bore stability problems arise. This effect has also been discussed in the literature.

A basic question arises when the reconstituted and native samples are analyzed. Does the reconstituted sample adequately represent the native condition? Several investigators have determined that once the rock fabric, or matrix, is altered, then the reconstituted sample can not be representative of the native rock. This is supported by data shown in Figure 14. The tensile strength for native intact dry Atoka was 1108 psi whereas the reconstituted strength was only 220.4 psi. The differences narrowed when the samples were placed in fluid, but this is most likely caused by the sample formation process discussed earlier.

The comparison between intact and reconstituted material is not so clear for PTX, however. The data in Figure 13 shows a good correlation between the reconstituted and native samples. The difference is less than 10 psi in the dry case and slowly grows to 87 psi in the 10% KCl case. A possible explanation for this is the sample preparation process approximated the original depositional process and subsequent compaction. The time in the load frame and fabrication pressure coincidentally reproduced the original process. However, this chance occurrence can not be relied upon when setting up an experimental program.

4.2 X-Ray Diffraction Analysis

Table 2 contains the X-Ray Diffraction (XRD) Analysis of the shales tested in this report. This analysis was performed at the Exploration and Production Technology Division of Texaco. XRD determines the overall clay content and the clay minerals present in the shale.

Table 2: XRD Analysis

SAMPLE TESTED	Clay % Fraction	Montmor-illonite	Mixed Layer	Kaolinite	Illite	Chlorite
GSB	88	100	0	0	0	0
PAC	53	0	78	12	0	10
PEF	66	53	0	28	19	0
PTX	57	82	0	0	11	7
TMC	44	0	42	25	33	0
TXA	33	15	0	33	13	39

Figures 15-18 show the relationship between the percent clay content and tensile strength. This weight percent is the total clay content from the above table. Figures 15 and 16, reconstituted dry and with demineralized water, respectively, show an increasing trend. As the percentage of clay increases, so does the tensile strength. The effect of KCl is to reverse this trend. As the clay content increases, the tensile strength decreases. The effect of KCl is greatest on the shales with a high

montmorillonite content (GSB and PTX).

4.3 Methylene Blue Capacity Test (MBT)

This test determines the cation exchange capacity of a shale and can give an indication of the clay content. The methylene blue test was performed at CESE by Earl Wharmund.[21] The MBT values are listed in Table 3, while Figures 19-22 show the relationship between the MBT and tensile strength values.

Table 3: MBT Capacities

GSB	91
PAC	18
PEF	30
PTX	27
TMC	21
TXA	N/A

The best relationship was exhibited by the reconstituted dry case, Figure 19. This linear relationship is best described by the fact the methylene blue test is designed for dry shales and would compare best to other dry samples.

4.4 Atterberg Limits

The Atterberg limits of a shale are usually reported for reconstituted material and describe the water content of the sample. The upper limit is known as the liquid limit and is the value at which the shale changes from a liquid to a plastic state.[7] More specifically, the liquid limit is the moisture content in the shale that causes it to flow when slightly jarred. The plastic limit is the lowest moisture content possible when the shale is rolled in 1/8 inch treads. This is called the semisolid state.[7]. The plasticity index is simply the difference between the liquid and plastic limits. Table 4 shows the Atterberg Limits for the shales tested in this study. These tests were performed at CESE by Earl Wahrmund.[21]

Table 4: Atterberg Limits

	LL	PL	PI
GSB	555	51	504
PAC	28	16	12
PEF	64	26	38
PTX	70	29	41
TMC	42	16	26
TXA	N/A	N/A	N/A

Figures 23 to 34 show the relationship between the Atterberg Limits and tensile strength.

4.5 Ensilin Test

The ensilin test carried out by Tom Redford[14] at CESE measures the amount of fluid adsorbed by a shale. The swelling index is defined as the y-intercept of the adsorption profile.[22] The values for the samples tested in this study are listed in Table 5.

Table 5: Ensilin Values (Gr fl/Gr sh)

	0% KCl	.5% KCl	15% KCl
GSB	5.8795	2.8823	1.2940
PAC	0.7551	0.8847	0.6998
PEF	1.4546	1.2808	0.9782
PTX	1.2210	1.0233	1.0518
TMC	0.9059	0.7972	0.6315
TXA	N/A	N/A	N/A

Figures 35-38 show the relationship between the swelling index and tensile strength. Again the reconstituted dry case shows the best linear relationship between the two tests.

4.6 Specific Surface Area

The specific surface area test determines the area exposed to

physical adsorption of molecules and is expressed as square meters per gram substance. Table 6 shows the specific surface area (SSA) as determined by Ali Mese.[9]

Table 6: Specific Surface Area (m^2/gr)

GSB	574
PAC	152
PEF	249
PTX	153
TMC	166
TXA	N/A

Figures 39-42 show the graphical relationship between the SSA and tensile strength values.

4.7 Capillary Suction Time Test

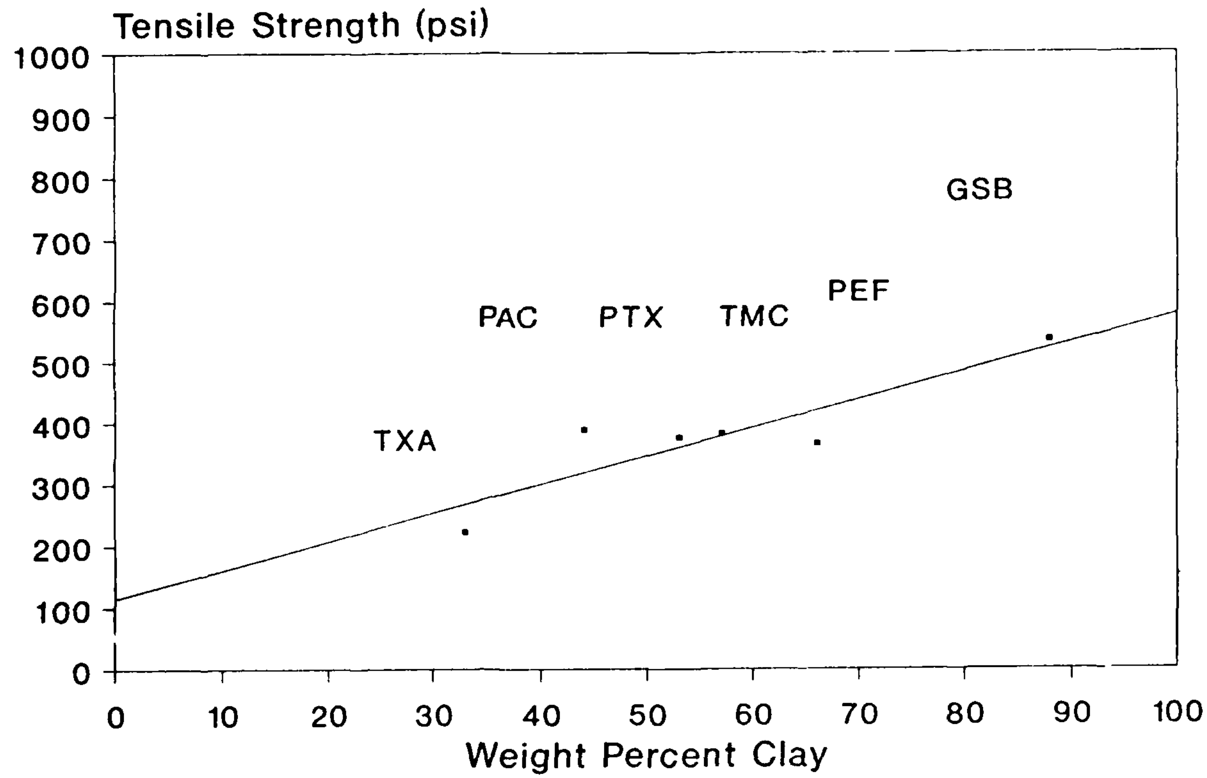
Kevin Hart[5] performed the capillary suction time (CST) test at CESE. This test measures the dispersive properties of shales by measuring the time required for mud filtrate to travel on a piece of filter paper. Table 7 shows the values obtained for the samples tested in this study.

Table 7: Capillary Suction Time (sec)

	0% KCl	.5% KCl	15% KCl
GSB	3547.0	470.0	10.0
PAC	76.5	20.8	11.0
PEF	52.6	40.5	14.3
PTX	179.0	21.2	12.5
TMC	105.0	39.3	13.5
TXA	N/A	N/A	N/A

Figures 42-46 graphically show the relationship between the two tests.

Figure 15. Weight % Clay vs TS
Company and Standard Shales (Dry)



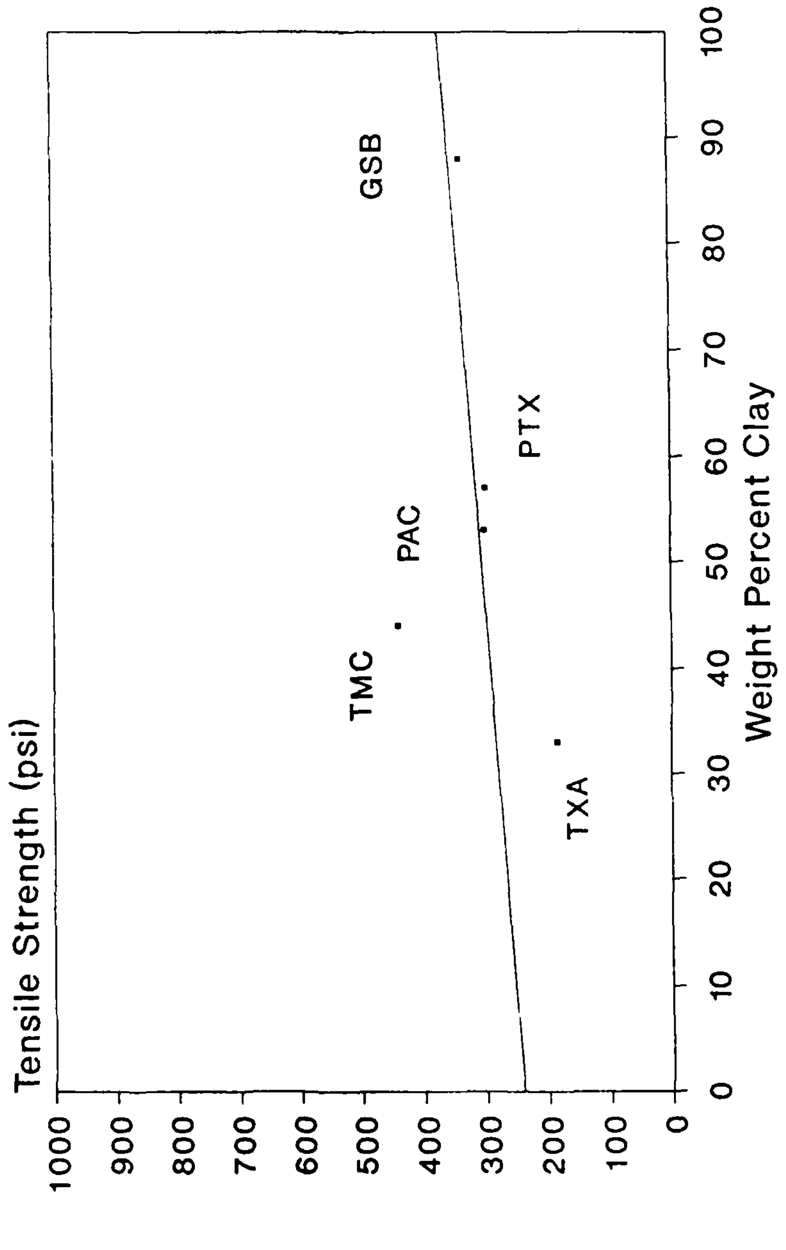


Figure 16. Weight % Clay vs TS
Reconstituted w Demin H2O

Figure 17. Weight % Clay vs TS
Reconstituted w 5% KCl

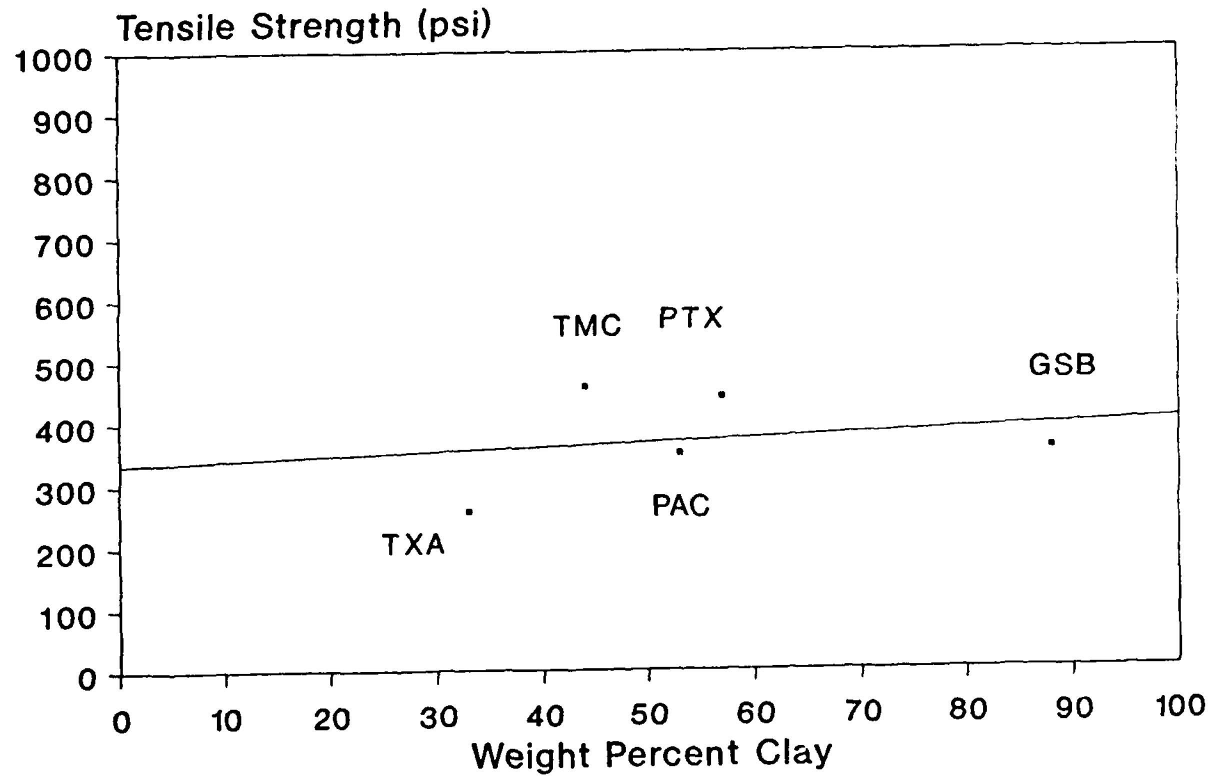


Figure 18. Weight % Clay vs TS
Reconstituted w 10% KCl

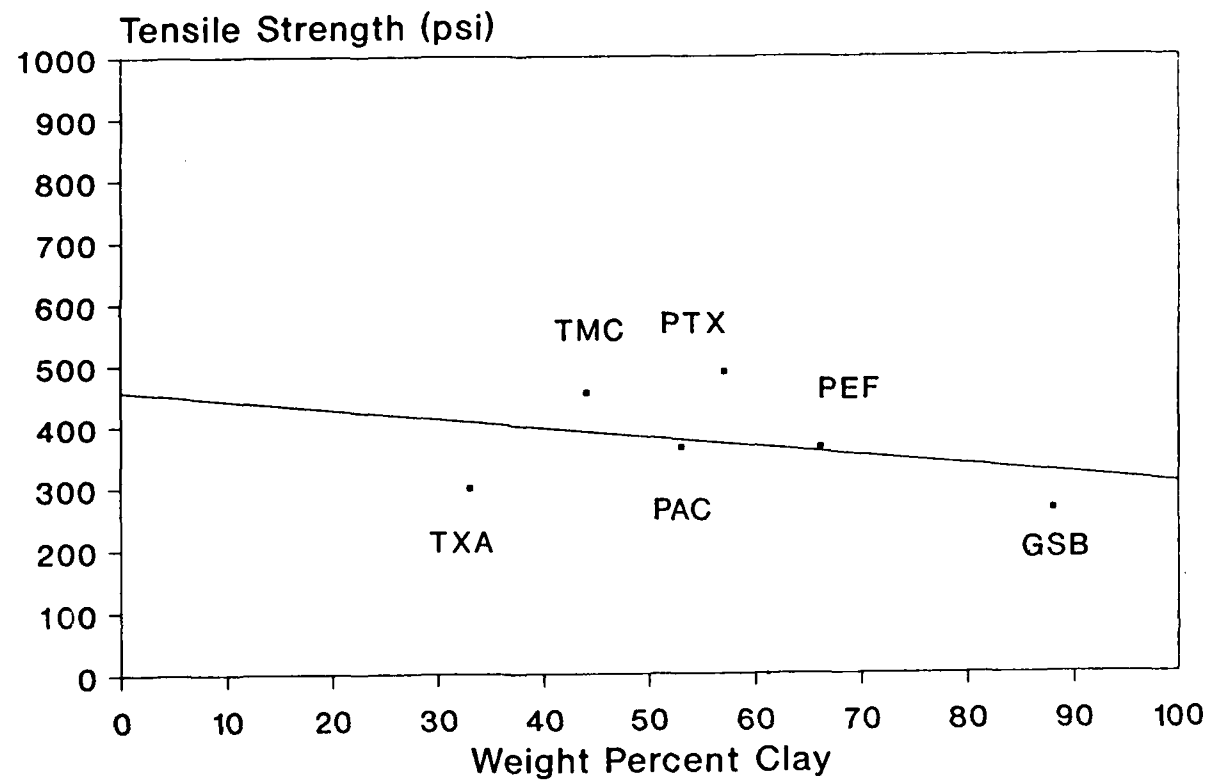


Figure 19. MBT vs Tensile Strength
Reconstituted Dry

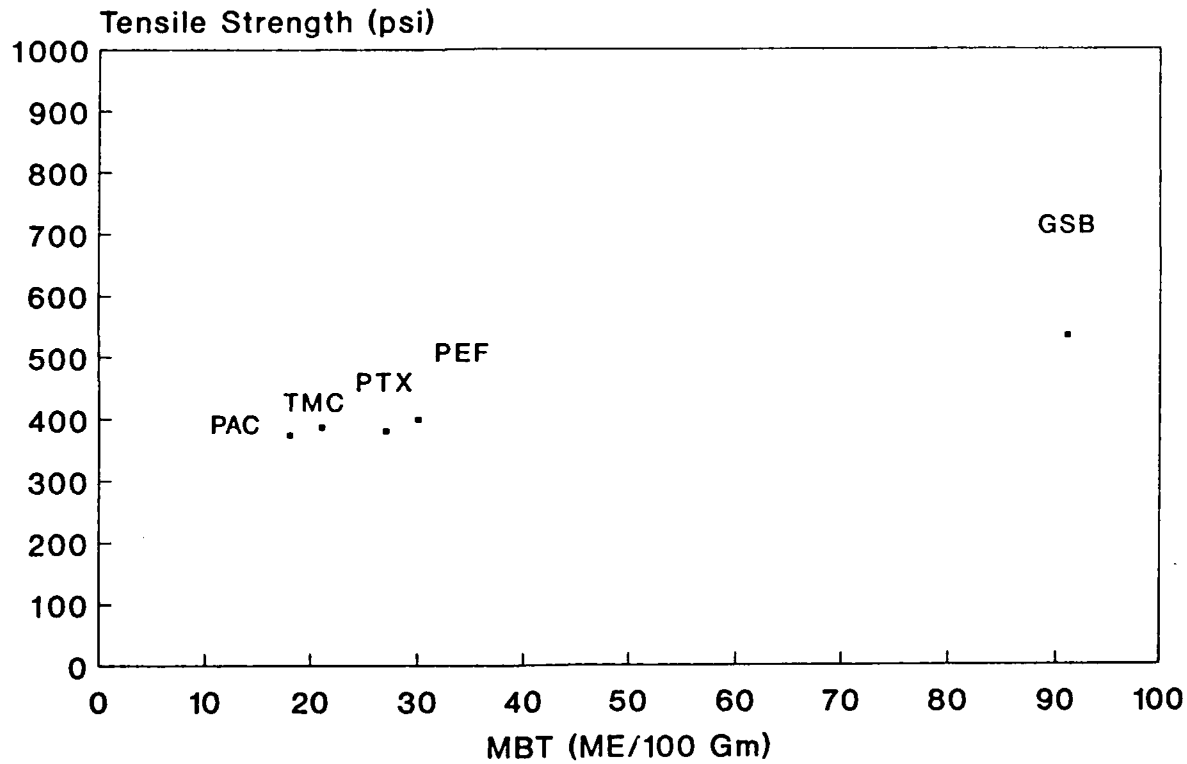


Figure 20. MBT vs Tensile Strength
Reconstituted w Demin. H2O

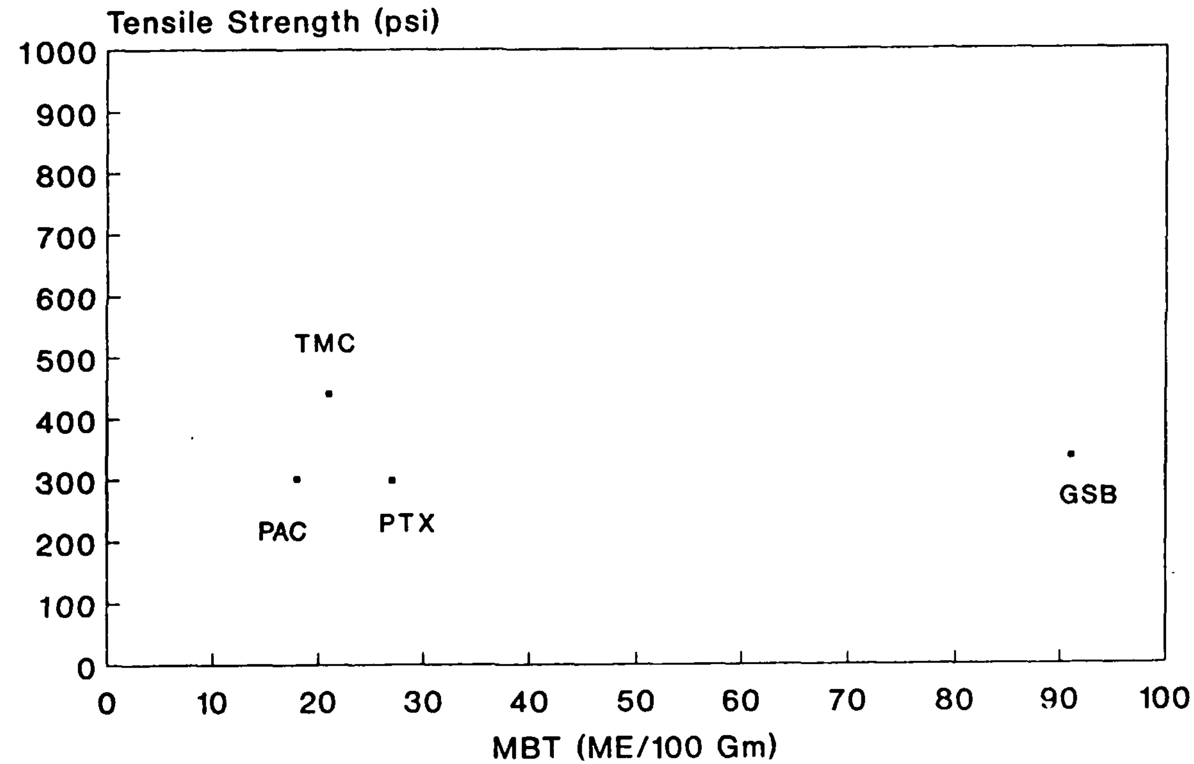


Figure 21. MBT vs Tensile Strength

Reconstituted w 5% KCL

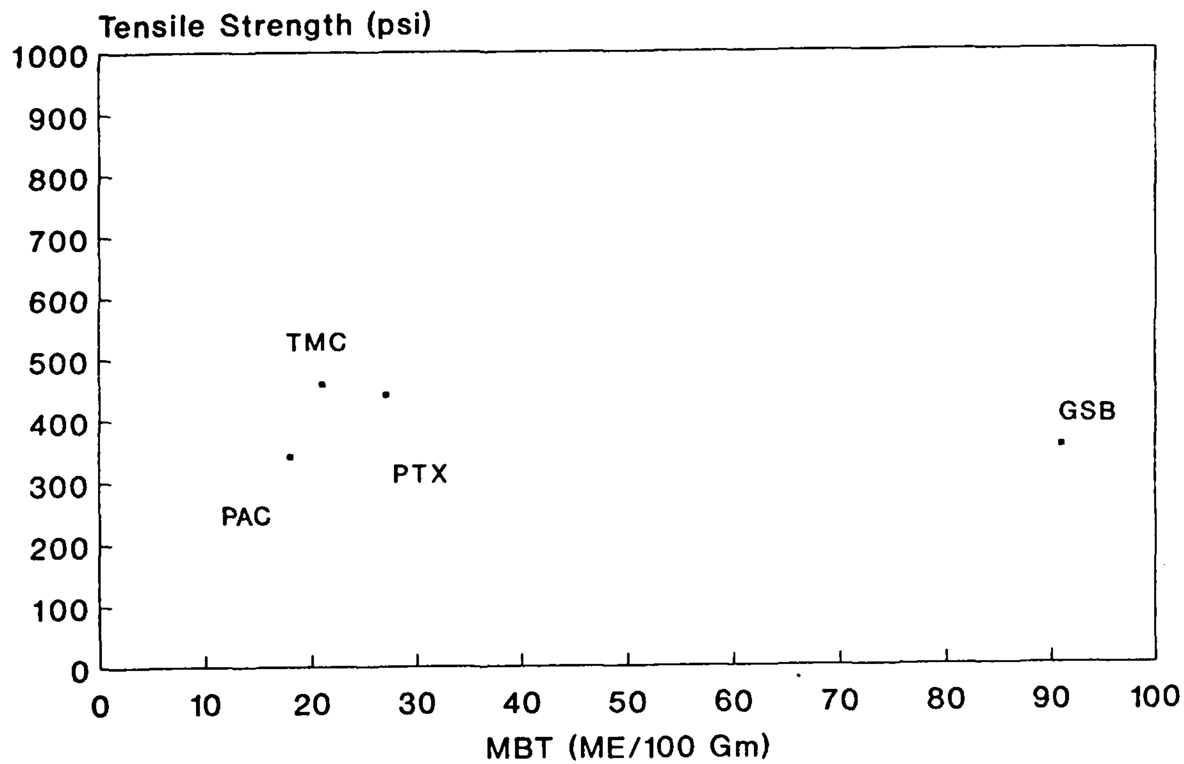


Figure 22. MBT vs Tensile Strength
Reconstituted w 10% KCL

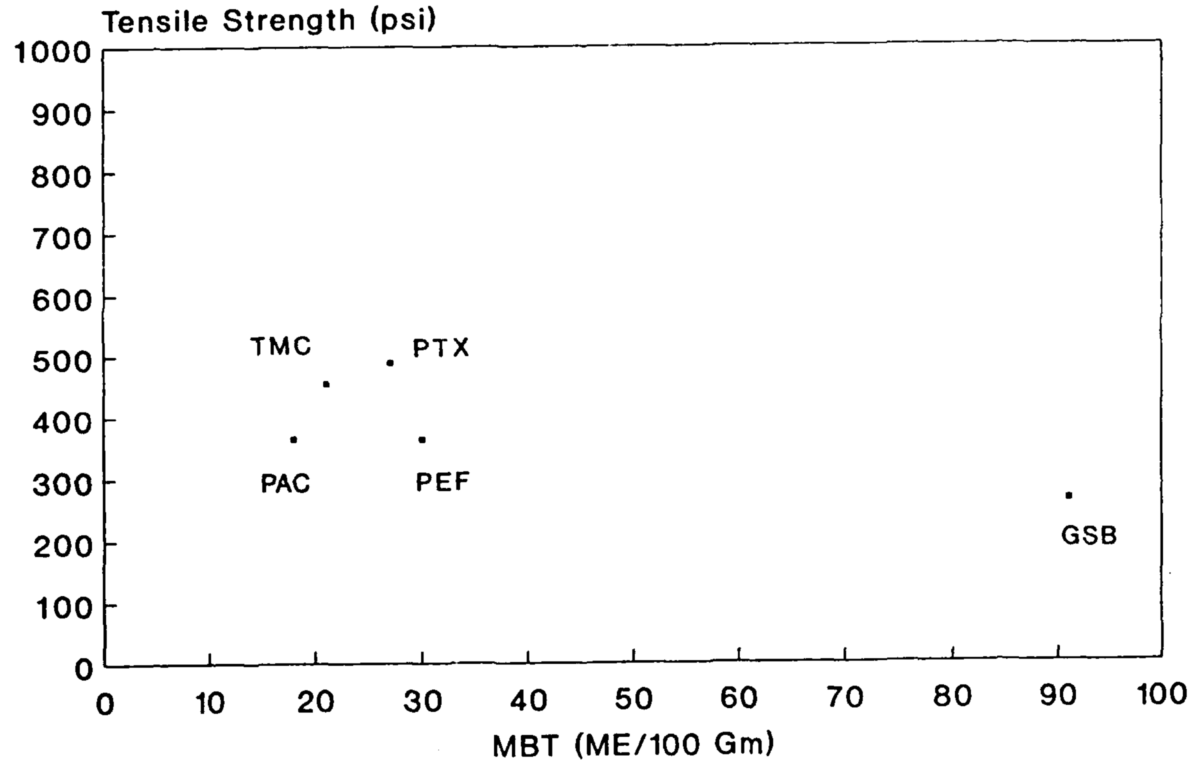


Figure 23. PL vs Tensile Strength

Reconstituted Dry

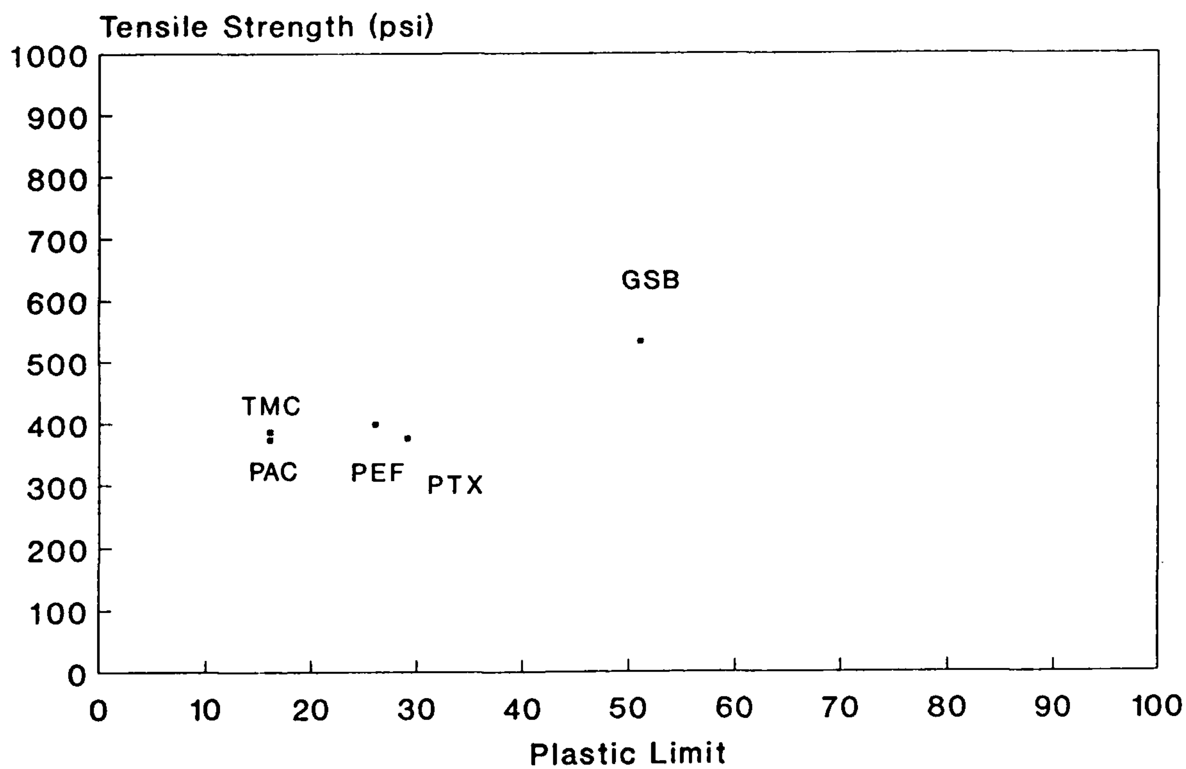


Figure 24. PL vs Tensile Strength

Reconstituted w Demin H2O

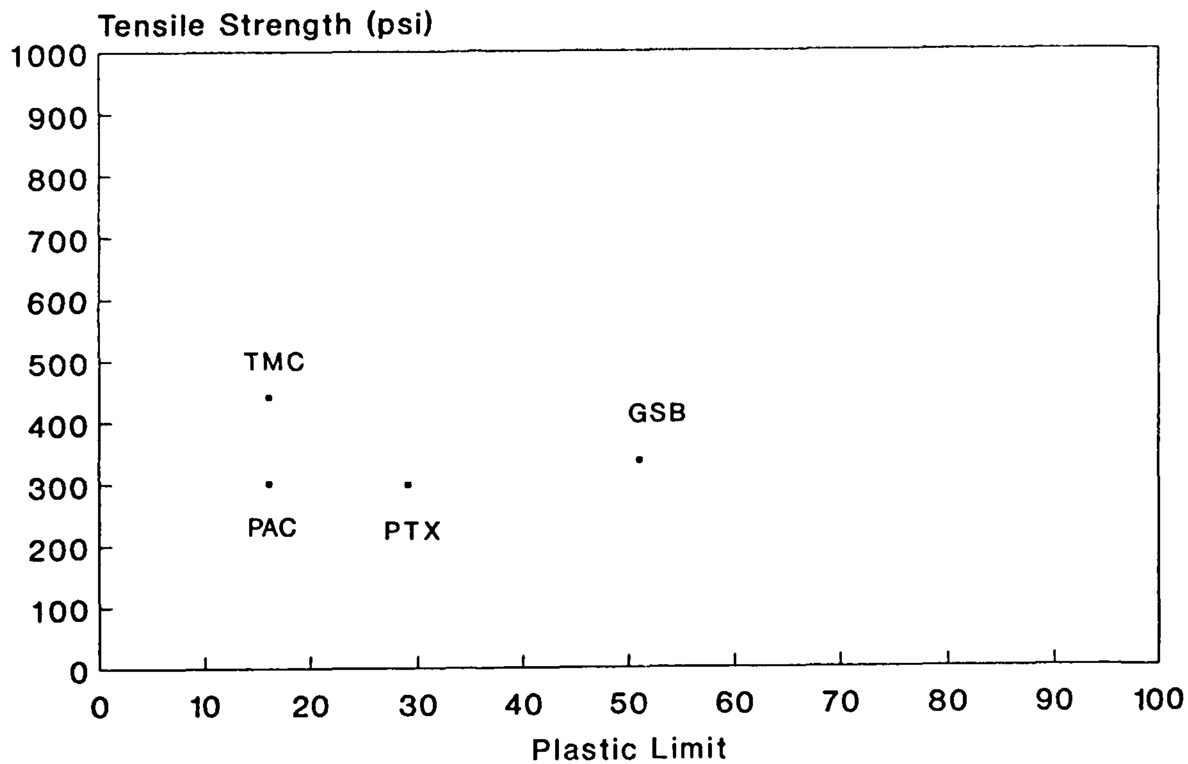


Figure 25. PL vs Tensile Strength

Reconstituted w 5% KCl

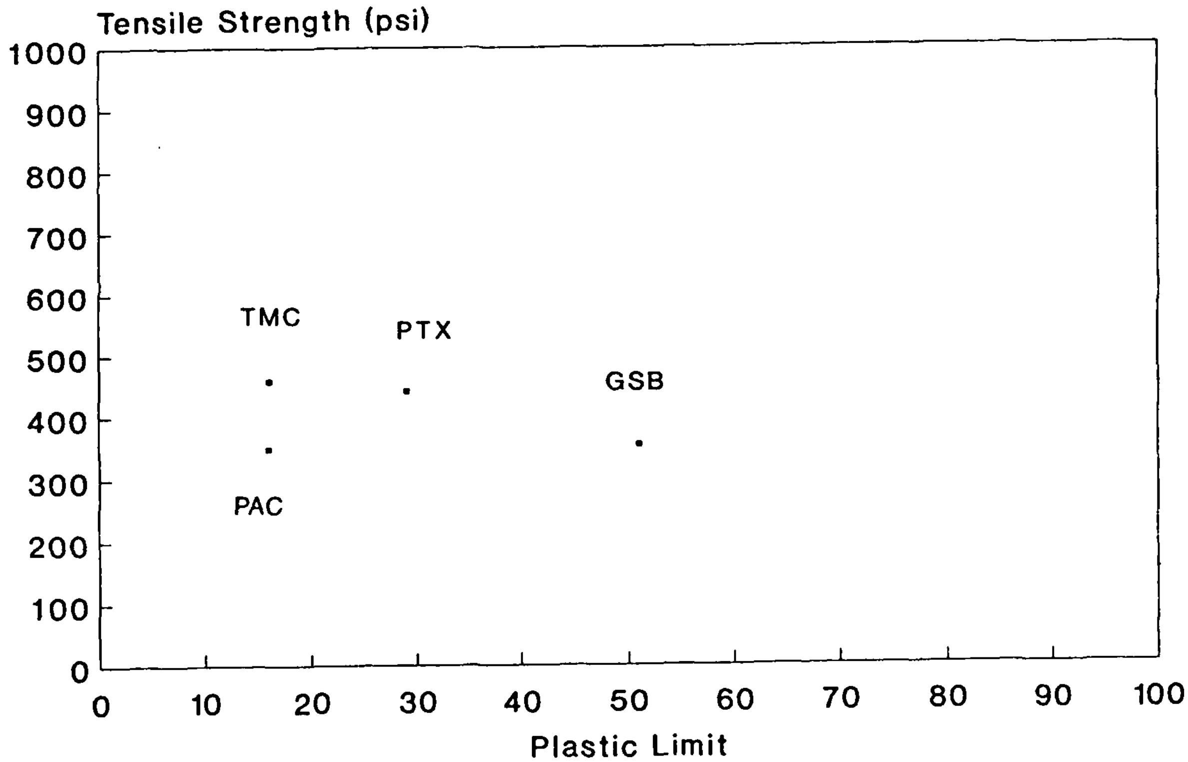


Figure 26. PL vs Tensile Strength

Reconstituted w 10% KCl

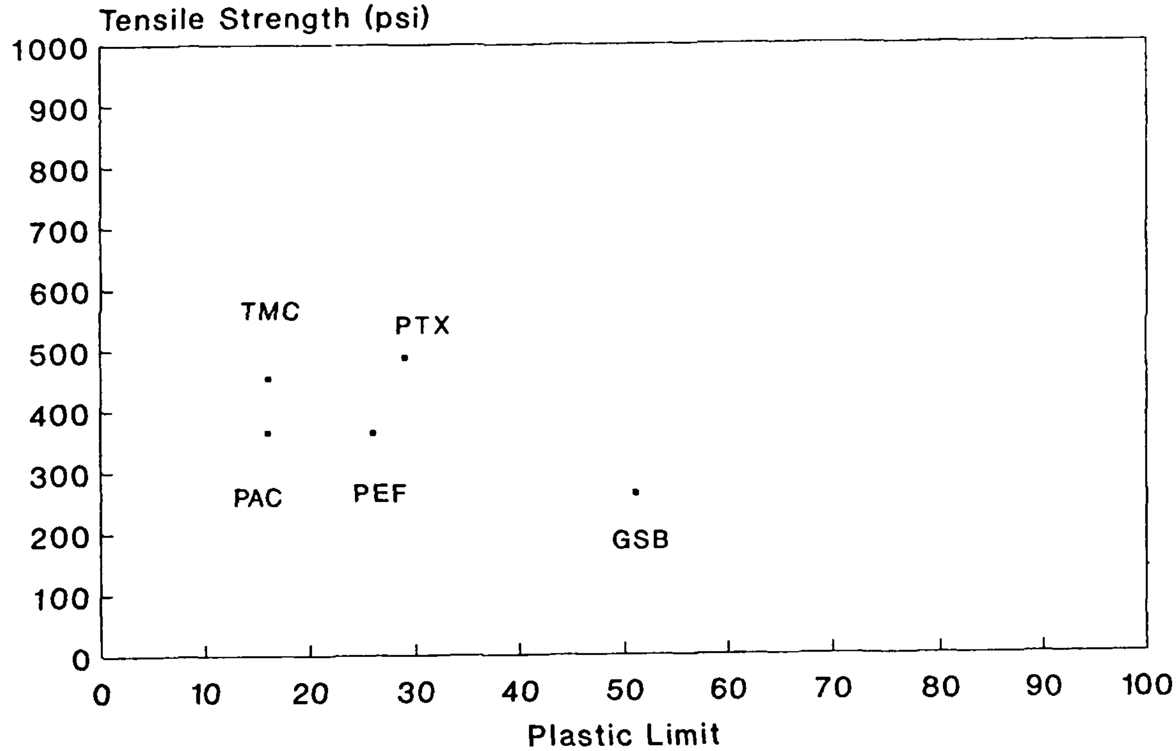


Figure 27. LL vs Tensile Strength

Reconstituted Dry

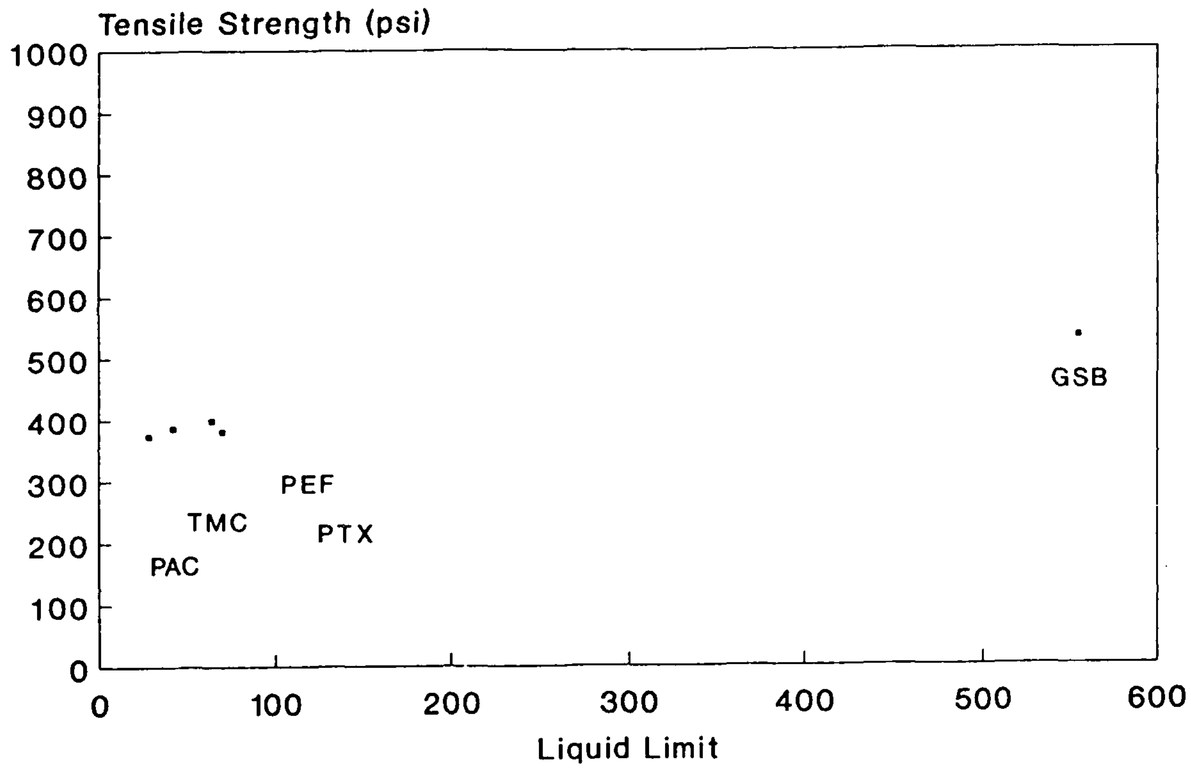


Figure 28. LL vs Tensile Strength
Reconstituted w Demin H2O

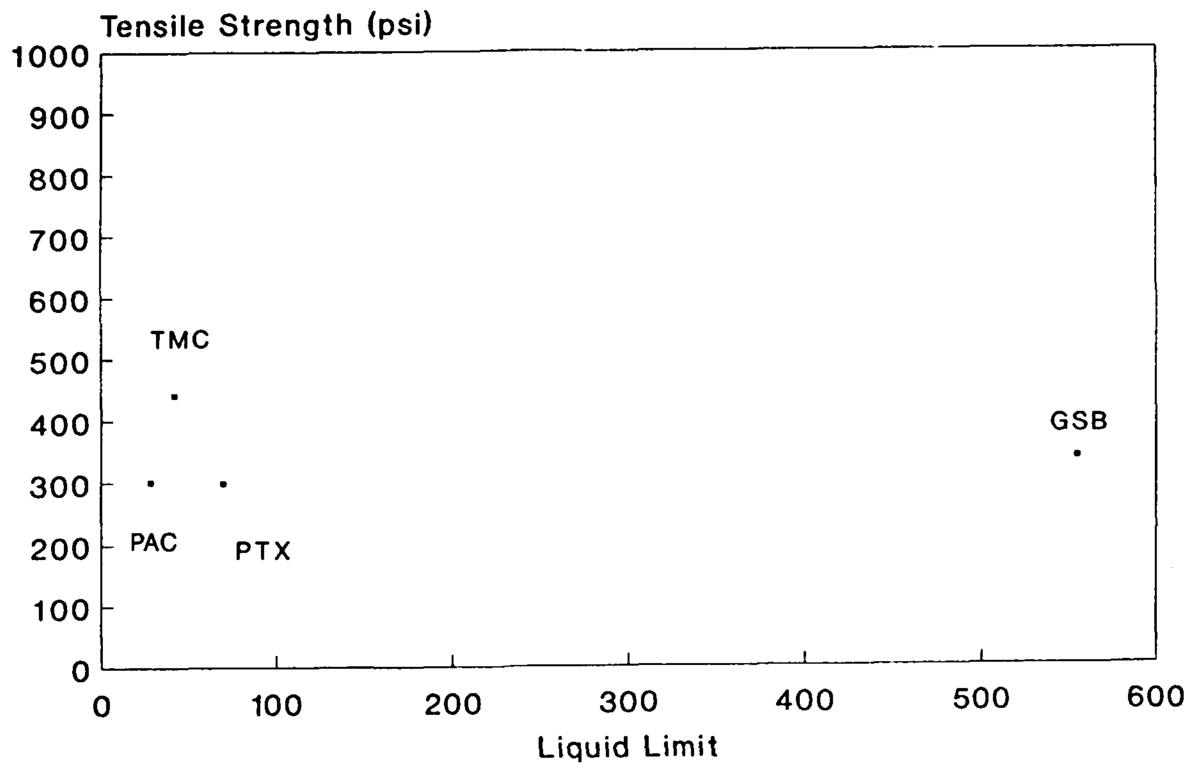


Figure 29. LL vs Tensile Strength
Reconstituted w 5% KCL

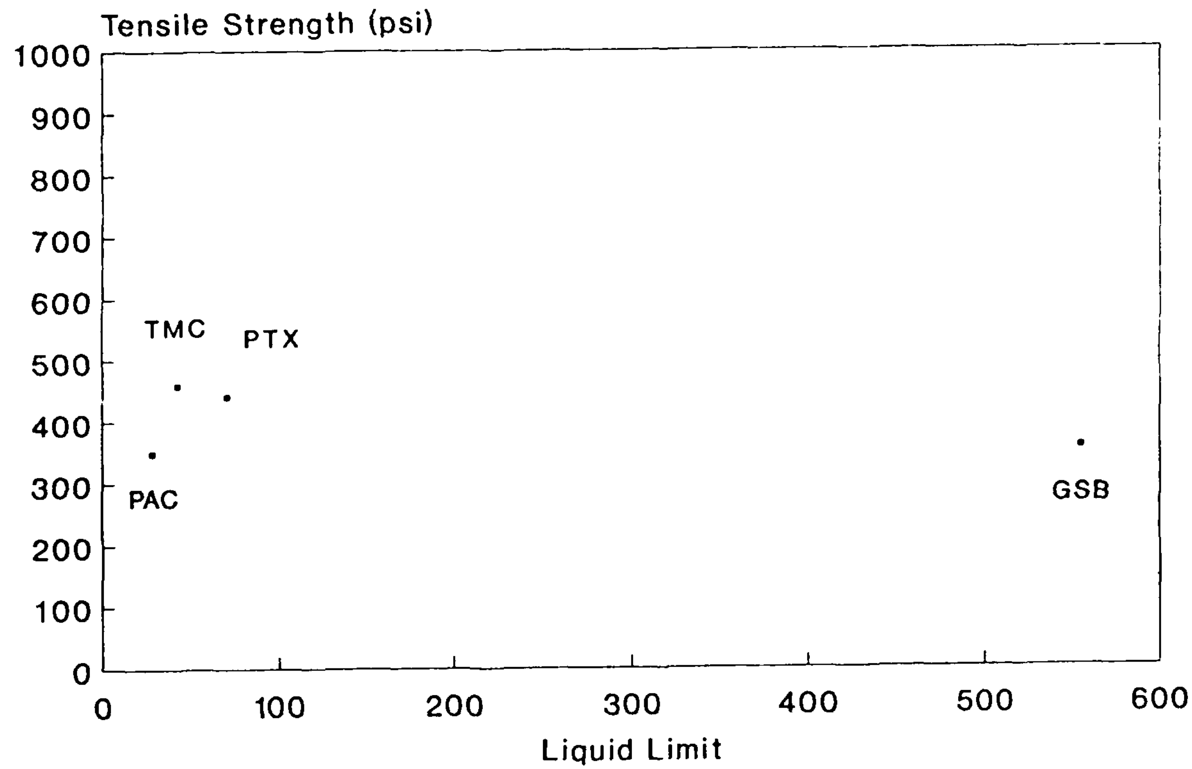


Figure 30. LL vs Tensile Strength

Reconstituted w 10% KCL

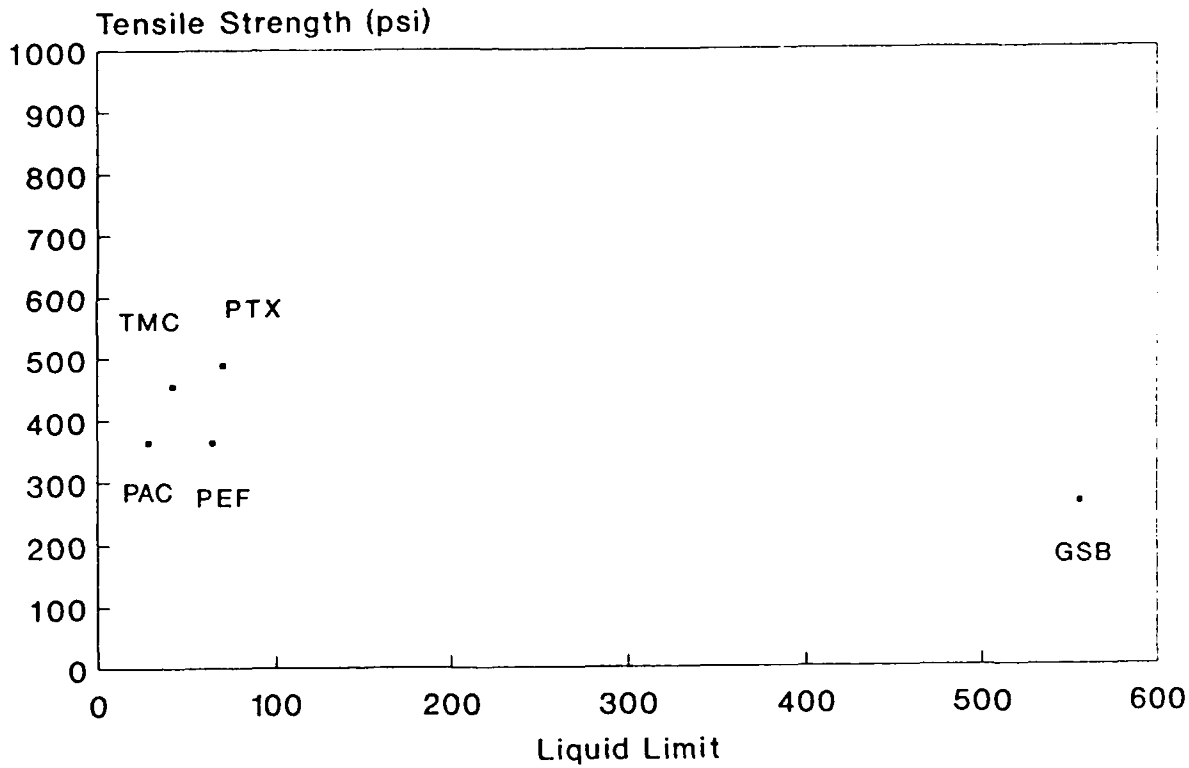


Figure 31. PI vs Tensile Strength
Reconstituted Dry

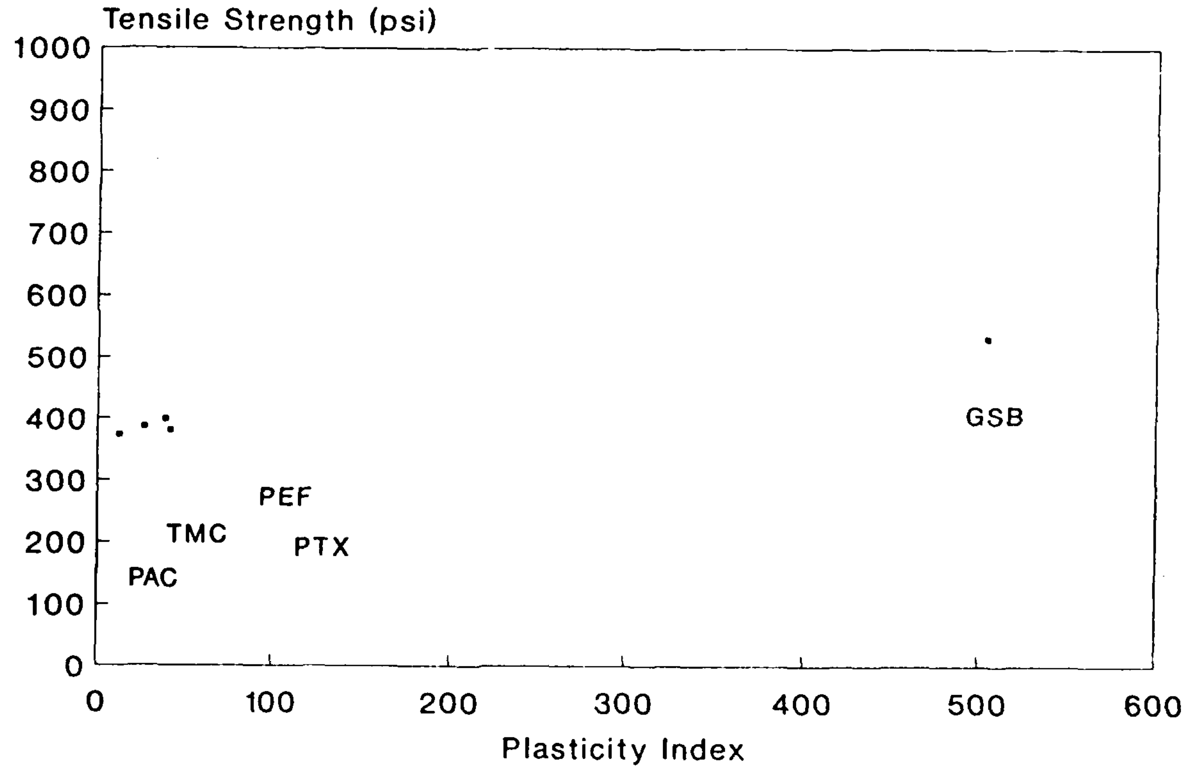


Figure 32. PI vs Tensile Strength

Reconstituted w Demin H2O

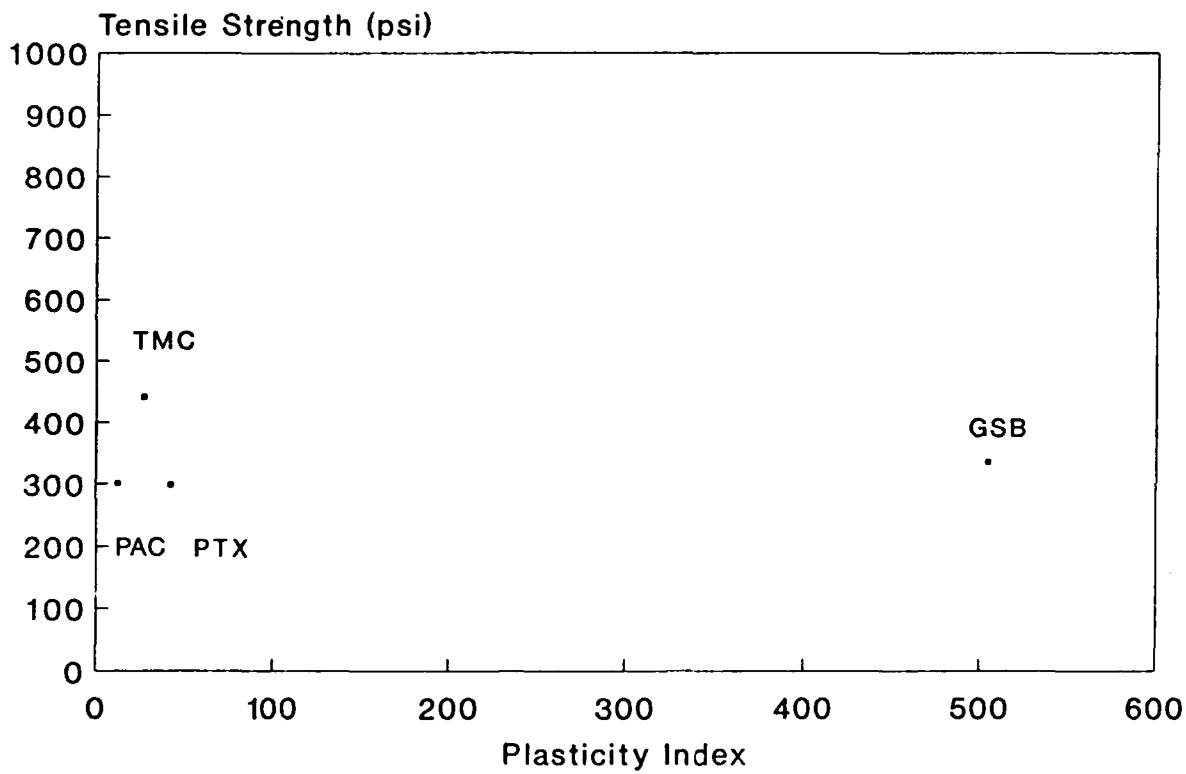


Figure 33. PI vs Tensile Strength
Reconstituted w 5% KCL

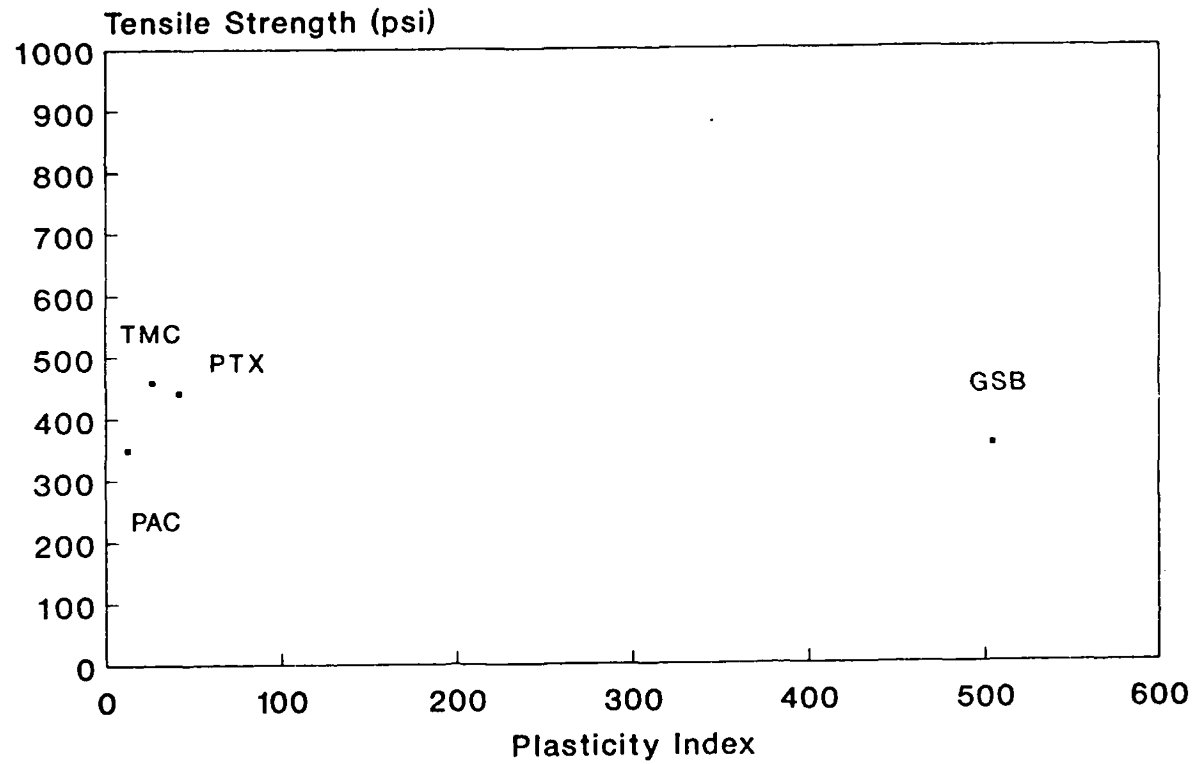


Figure 34. PI vs Tensile Strength
Reconstituted w 10% KCL

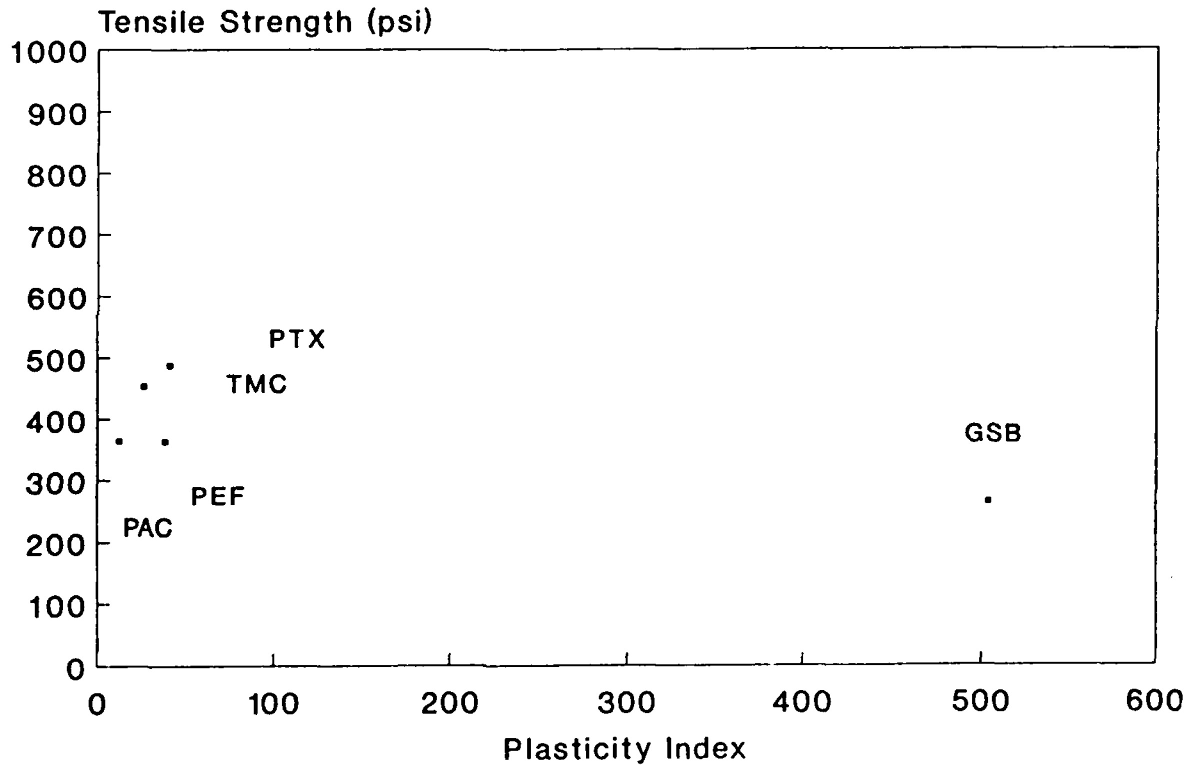


Figure 35. SI vs Tensile Strength
Reconstituted Dry

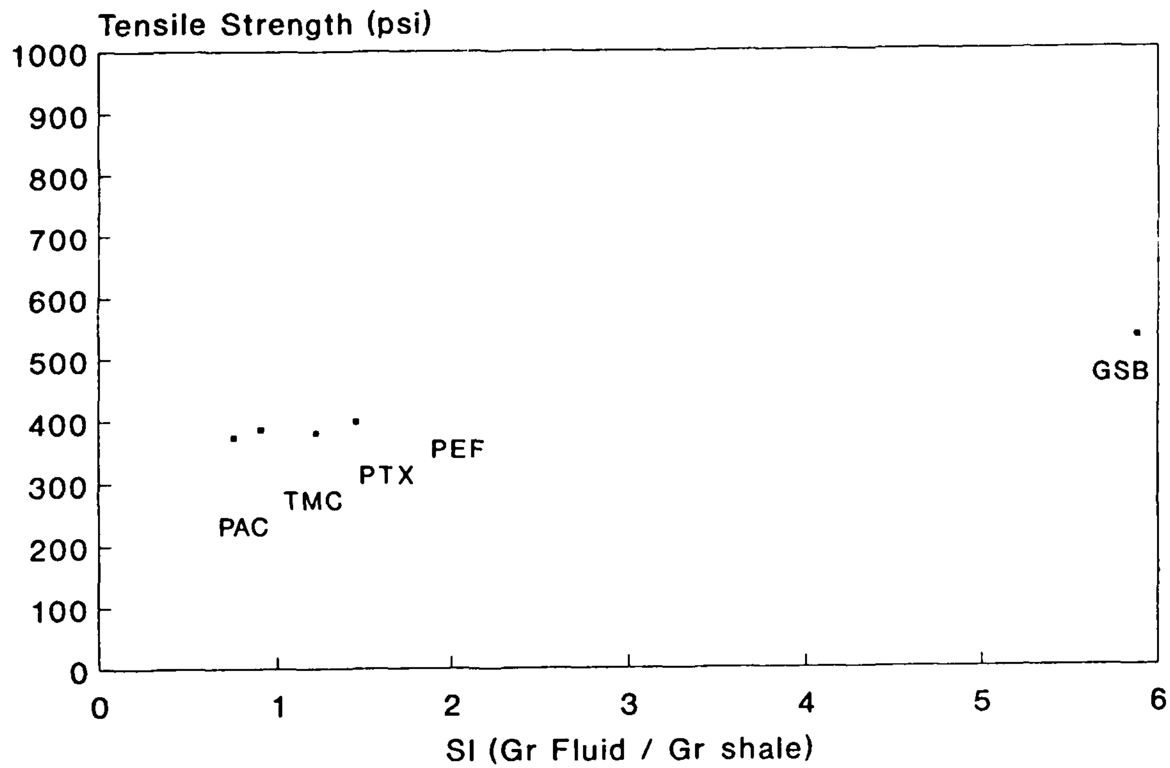


Figure 36. SI vs Tensile Strength

Reconstituted w Demin. H2O

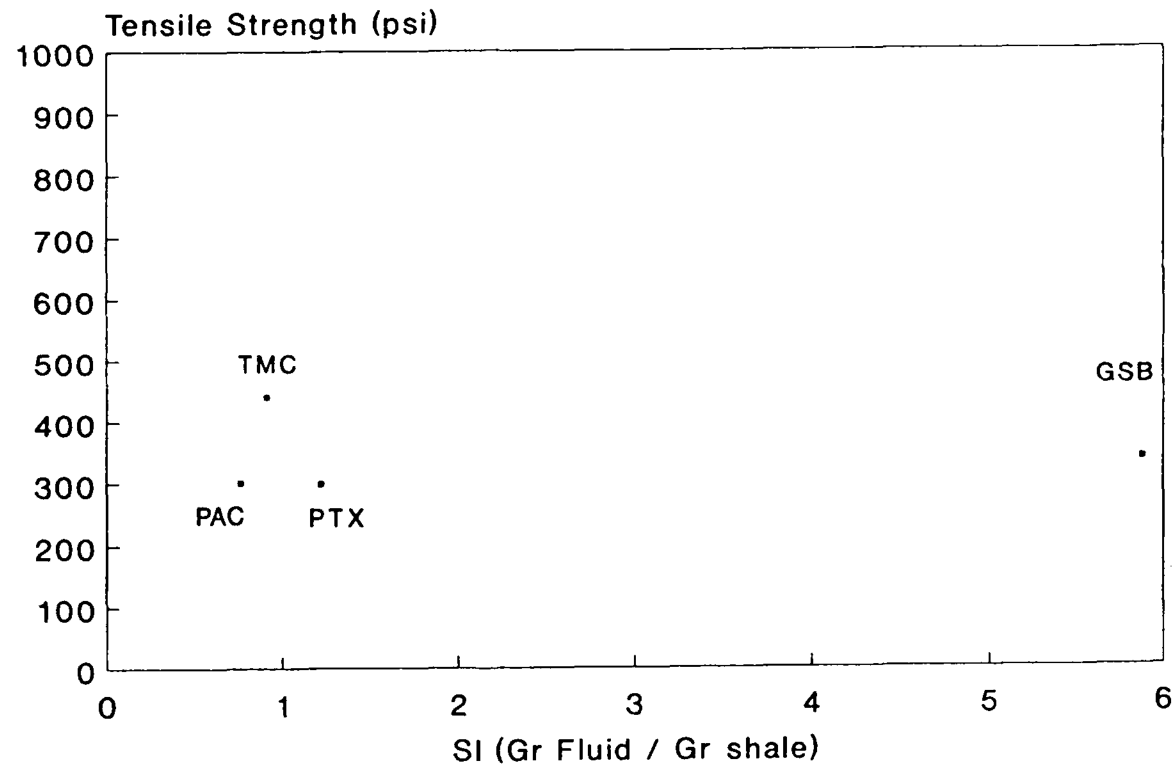


Figure 37. SI vs Tensile Strength

Reconstituted w 5% KCl

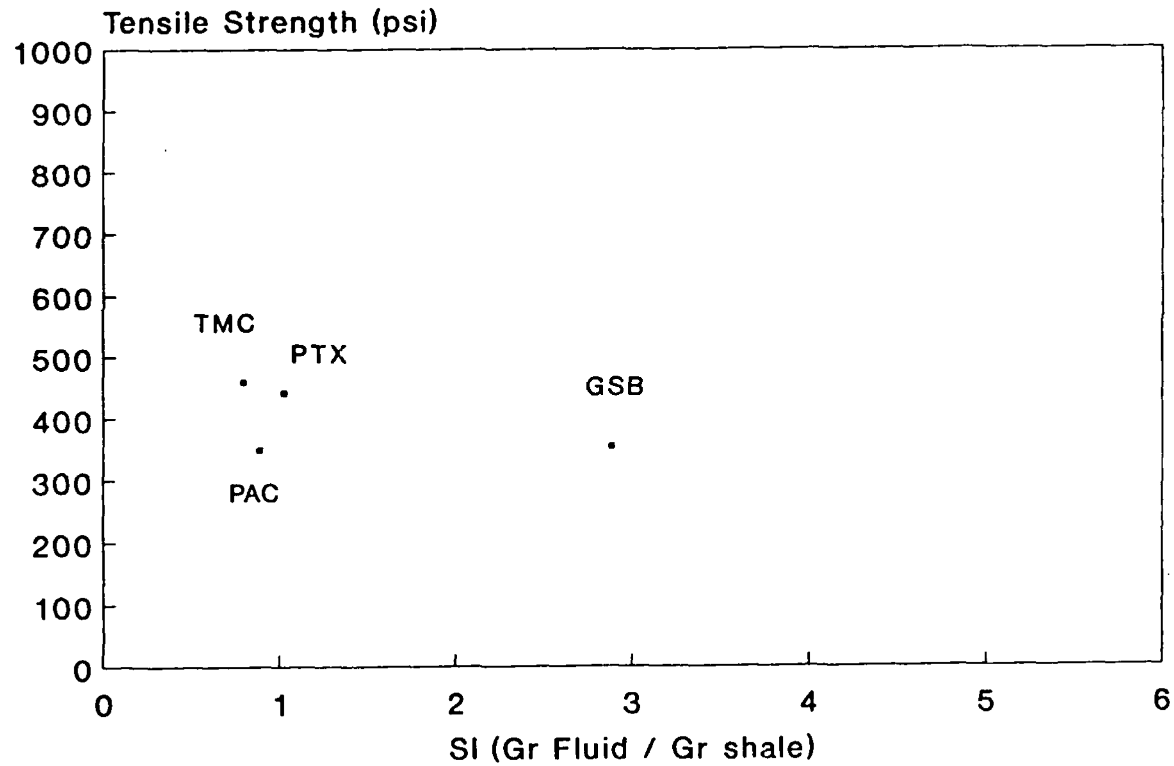


Figure 38. SI vs Tensile Strength
Reconstituted w 10% KCl

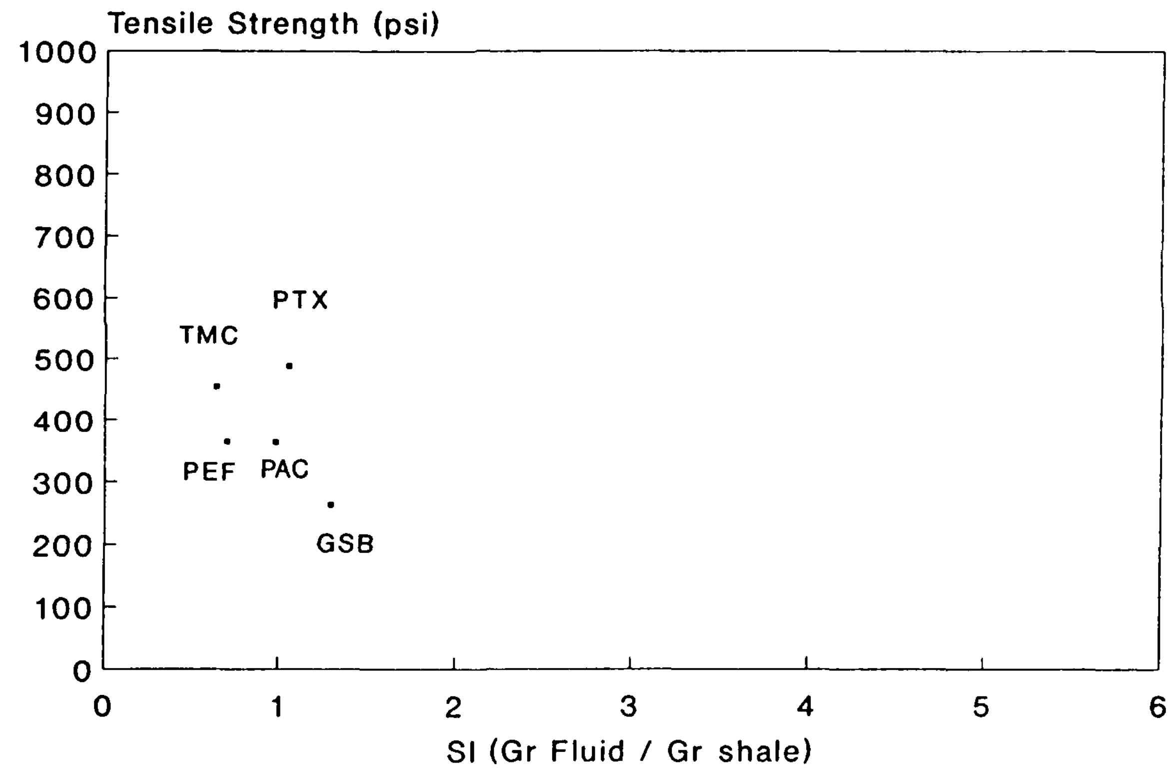


Figure 39. SSA vs Tensile Strength

Reconstituted Dry

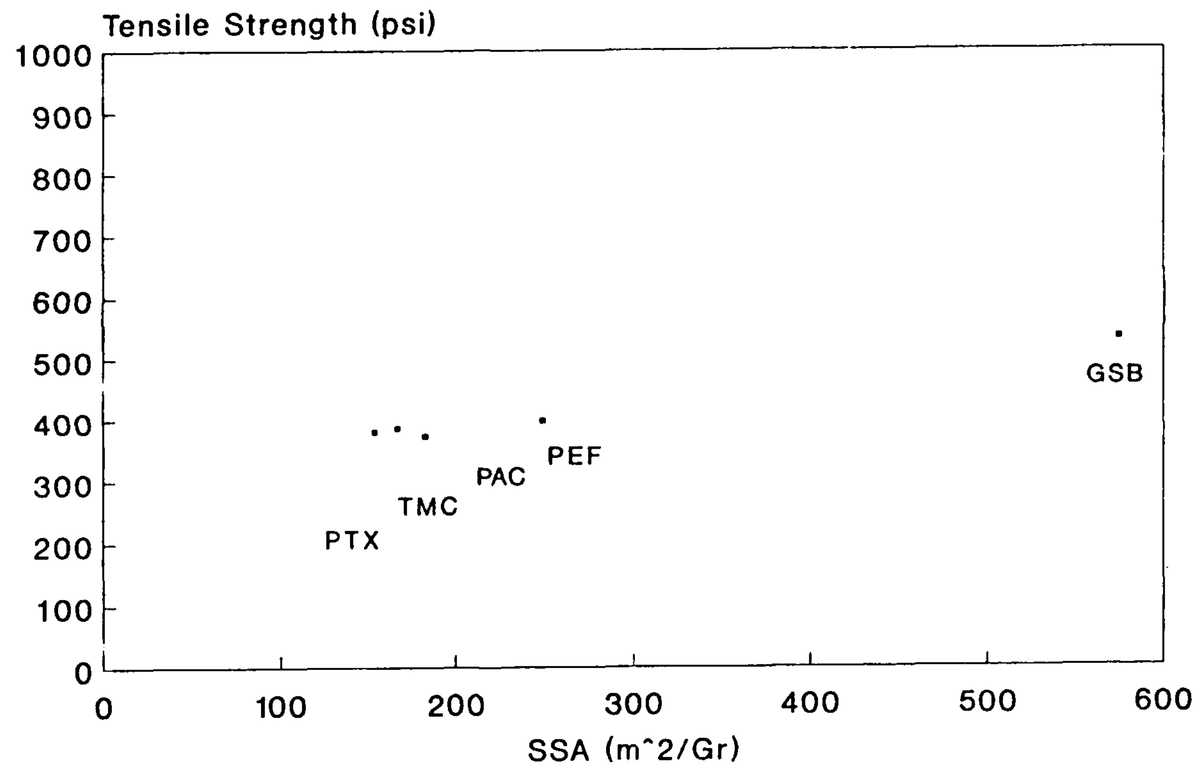


Figure 40. SSA vs Tensile Strength
Reconstituted w Demin. H2O

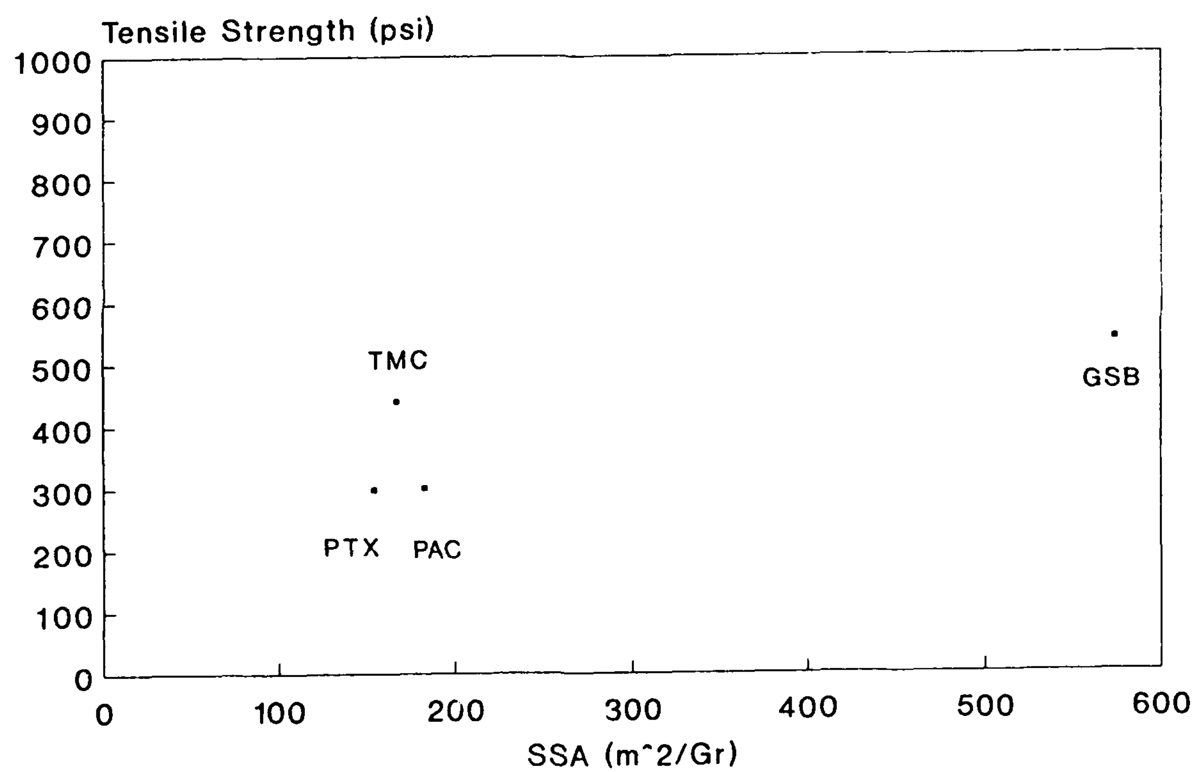


Figure 41. SSA vs Tensile Strength
Reconstituted w 5% KCl

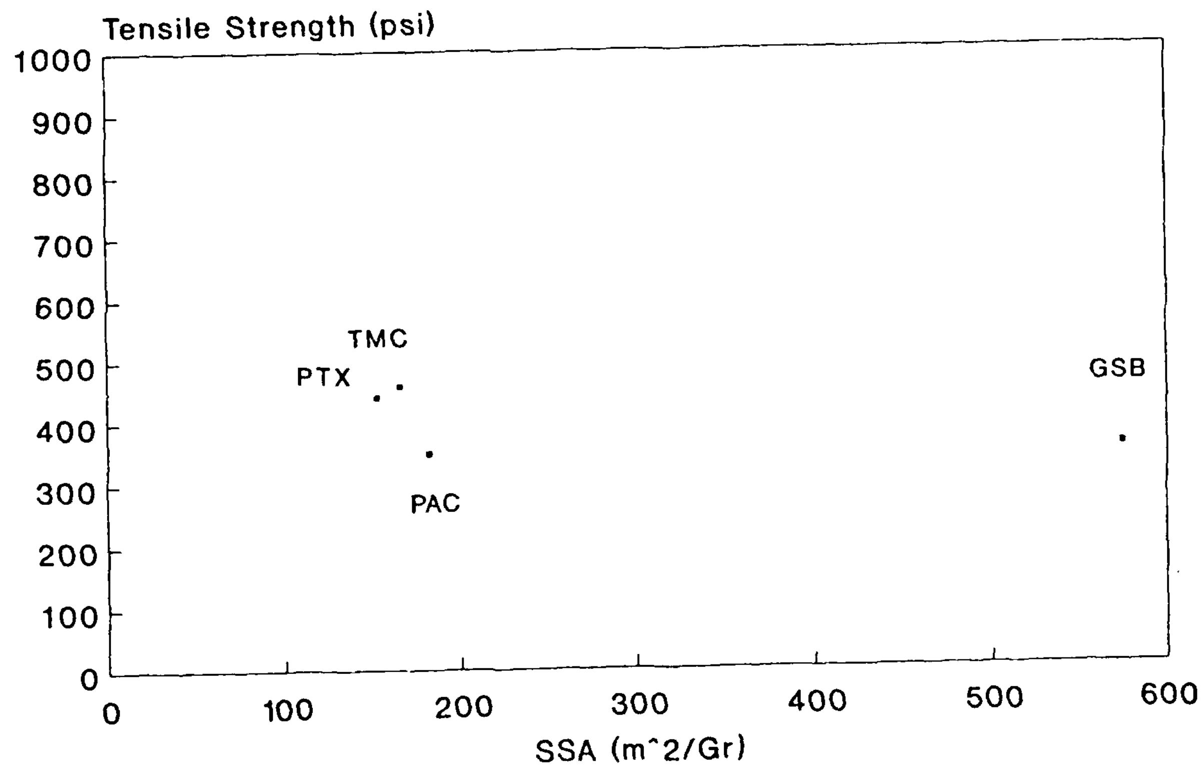


Figure 42. SSA vs Tensile Strength
Reconstituted w 10% KCl

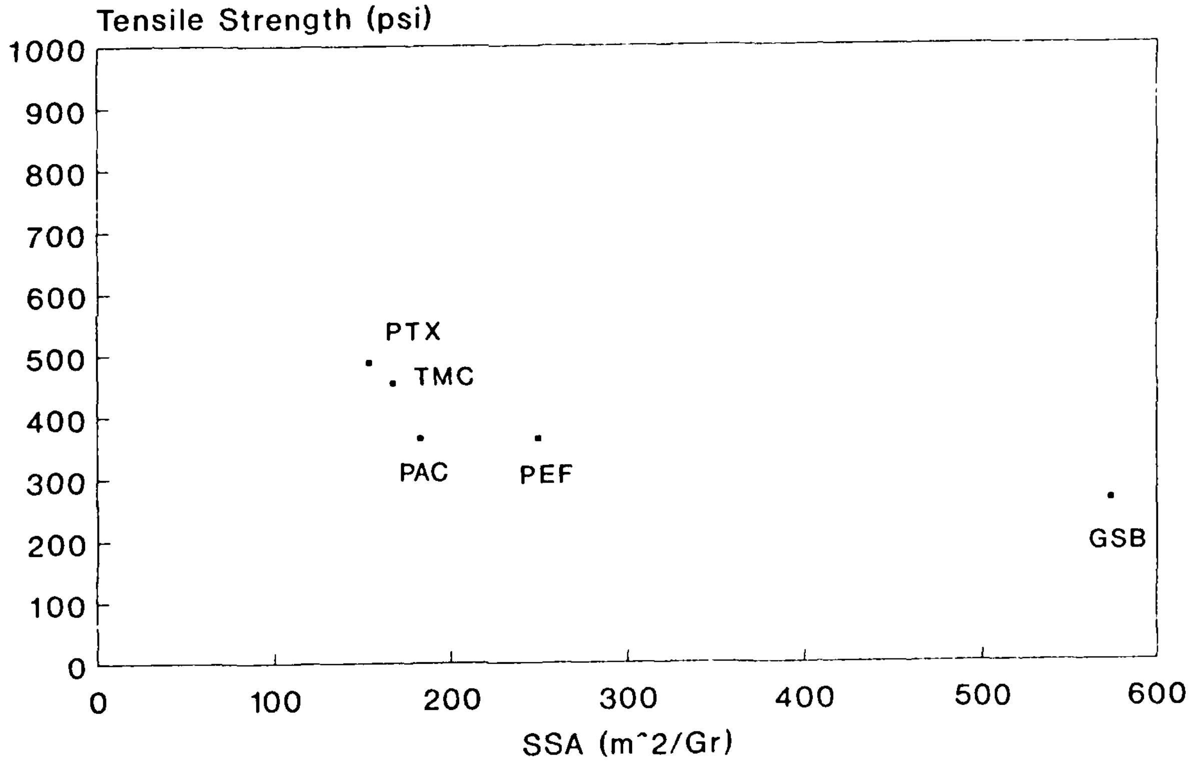


Figure 43. CST vs Tensile Strength

Reconstituted Dry

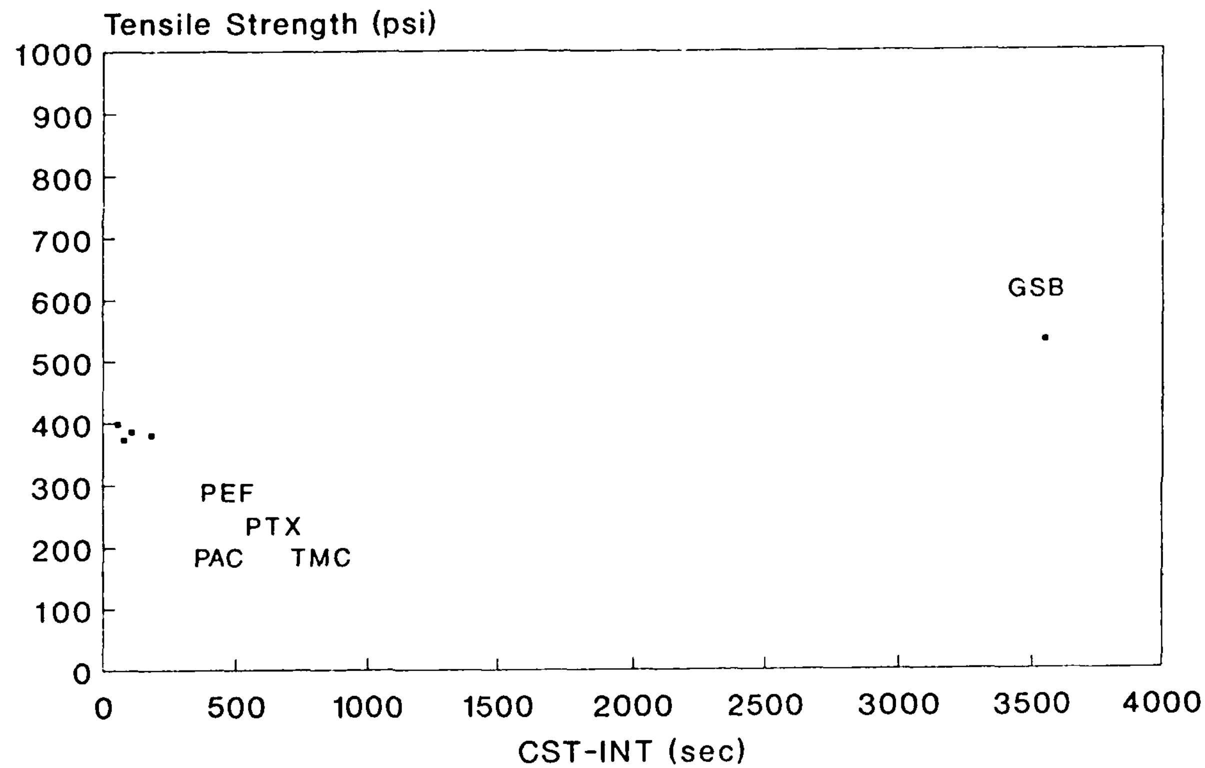


Figure 44. CST vs Tensile Strength
Reconstituted w Demin. H2O

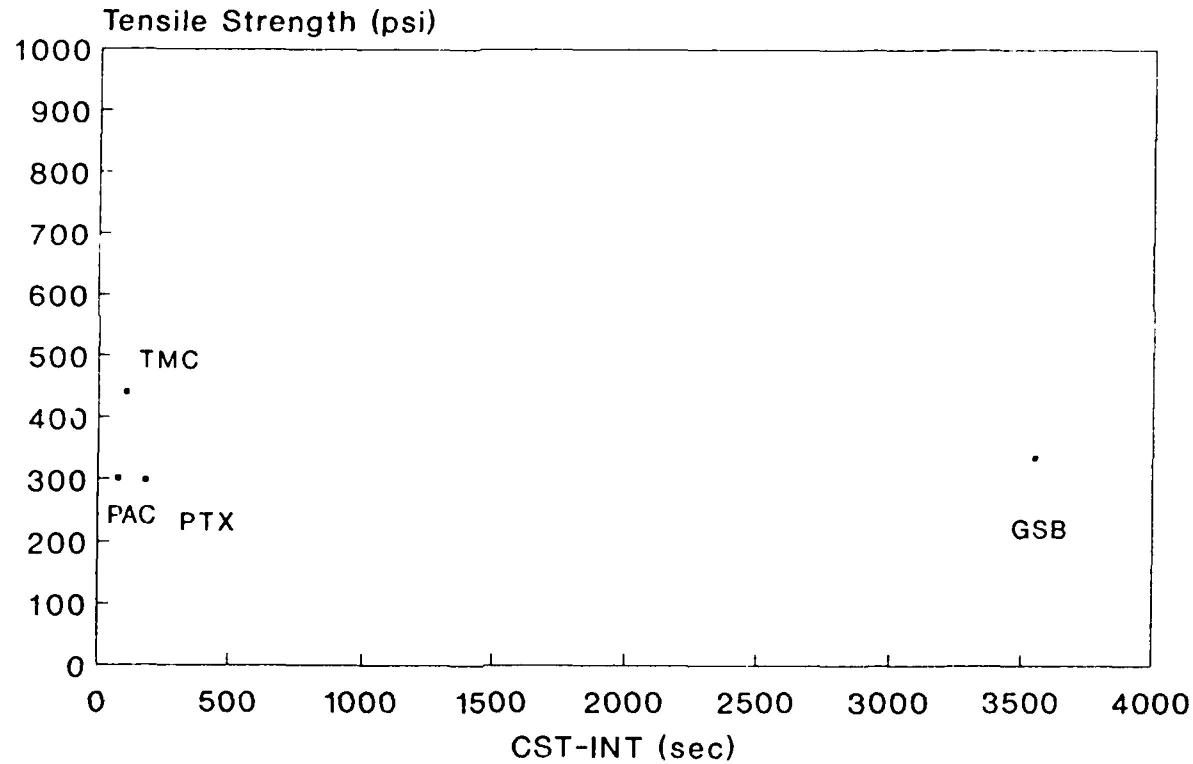


Figure 45. CST vs Tensile Strength
Reconstituted w 5% KCl

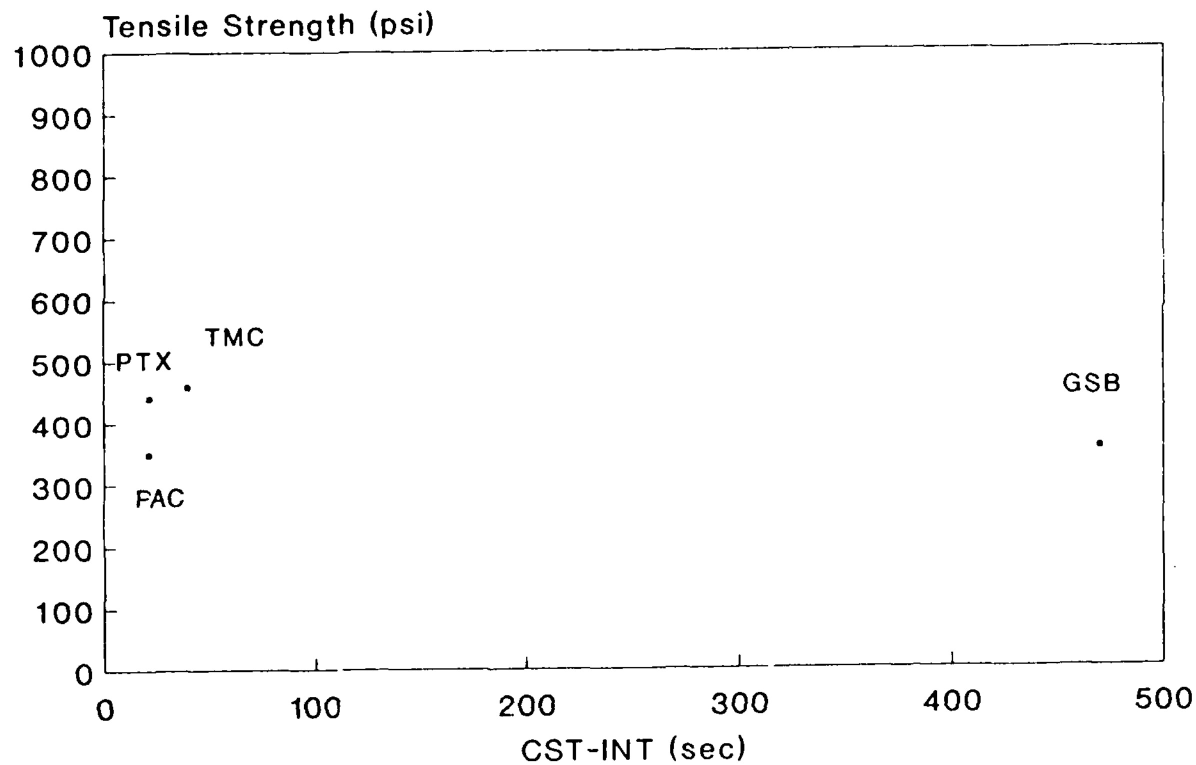
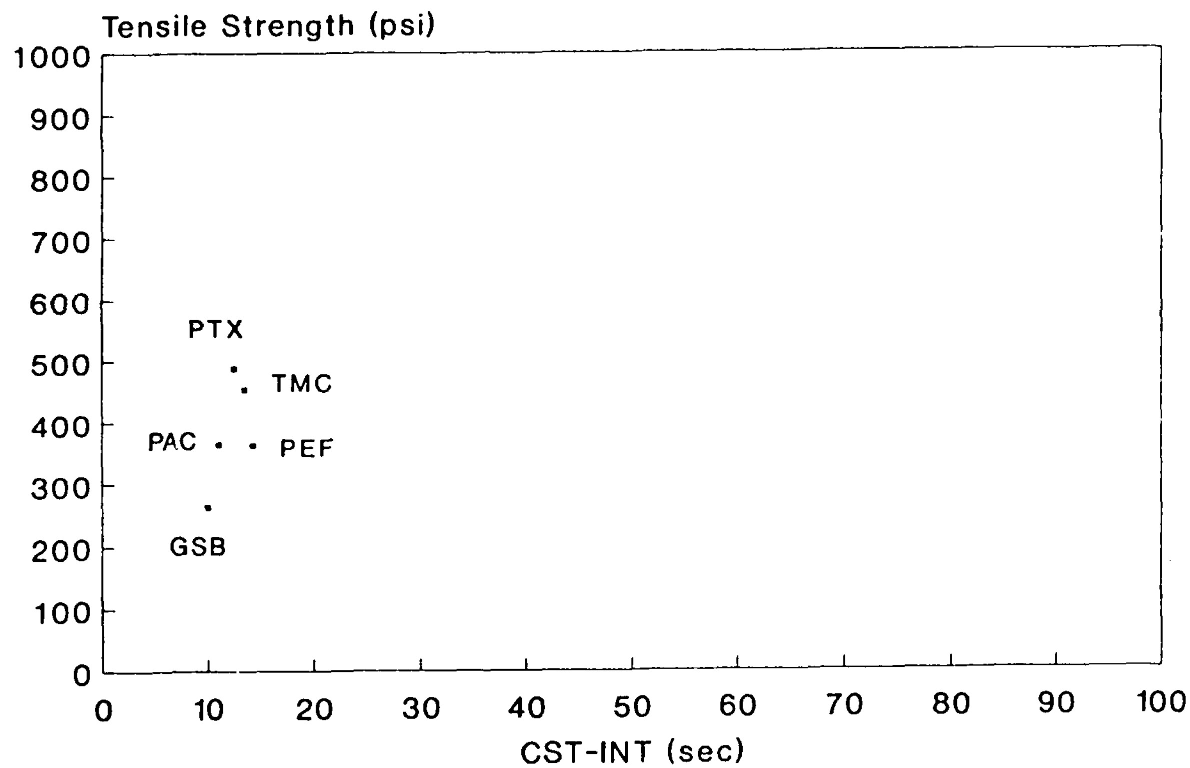


Figure 46. CST vs Tensile Strength
Reconstituted w 10% KCl



CHAPTER FIVE
CONCLUSIONS

Several conclusions can be made after analyzing the Brazilian tensile strength data.

The Brazilian method of tensile testing rock materials is a quick and efficient method of obtaining tensile strengths. However, due to disagreements in the values when compared with other tensile testing methods, the results from the Brazilian method should be used qualitatively.

There is little or no correlation between reconstituted and native intact rock samples when analyzed for tensile strength.

Within the resolution of the measurements conducted, the effect of confining pressure is an additive effect on the tensile strength.

The tensile strength is strongly effected by the presence of fluids. For the most part, demineralized water tends to decrease the tensile strength, while KCl solutions tend to increase the strength.

The tensile strengths obtained for the dry reconstituted case form linear relationships with the total weight percent clay, methylene blue capacity, liquid limit, plasticity index, swelling index, specific surface area and capillary suction intercept.

As a closing recommendation for areas of further study; it is recommended that a better way of introducing a fluid into the sample be found which would yield better and more accurate tensile data determining the fluid's effect on this value.

APPENDIX A
EXPERIMENTAL DATA

Tables 8-38 show the raw experimental data for the Brazilian tensile strength tests. Tables 8 through 29 represent reconstituted samples, while Table 30-37 represent native, intact samples. Table 38 tabulates the data obtained at elevated pressure.

Table 8

SAMPLE TESTED
GOLD SEAL BENTONITE dry
CONFINING PRESSURE = atmsopheric

	RUN#1	RUN#2	RUN#3	RUN#4	RUN#5
WT APP+SAMPLE	540.5840 gr	617.3959 gr	540.5619 gr	615.1458 gr	620.2025 gr
WT APP	528.5841 gr	605.3938 gr	528.5614 gr	603.1441 gr	608.2000 gr
WT SAMPLE	11.9999 gr	12.0021 gr	12.0005 gr	12.0017 gr	12.0025 gr
AVER THICKNESS	0.3210 in	0.3310 in	0.3170 in	0.3300 in	0.3200 in
AVER DIAMETER	1.1290 in	1.1310 in	1.1230 in	1.1370 in	1.1290 in
FAILURE LOAD	402.9900 lbs	496.9200 lbs	370.0500 lbs	370.0000 lbs	479.2500 lbs
TENSILE STRENGTH	509.6942 psi	608.4295 psi	476.4702 psi	452.0034 psi	608.0406 psi
DENSITY	2.2787 g/cc	2.2025 g/cc	2.3323 g/cc	2.1858 g/cc	2.2863 g/cc

AVER TS 530.93 psi
AVER DENS 2.2571 g/cc

Table 9

SAMPLE TESTED
GOLD SEAL BENTONITE w Demin H2O
CONFINING PRESSURE = atmospheric

	RUN#1	RUN#2	RUN#3	RUN#4
WT SAMPL WET	13.0256 gr	13.1822 gr	13.1029 gr	12.4930 gr
WT SAMPL+PAPER(DRY)	13.1054 gr	12.5124 gr	12.1650 gr	13.4919 gr
WT PAPER (DRY)	2.0968 gr	1.0456 gr	0.8556 gr	2.6884 gr
WT SAMPLE	11.0086 gr	11.4668 gr	11.3094 gr	10.8035 gr
WT H2O	2.0170 gr	1.7154 gr	1.7935 gr	1.6895 gr
% WATER	15.48	13.01	13.69	13.52
AVER THICKNESS	0.3730 in	0.3678 in	0.3645 in	0.3548 in
AVER DIAMETER	1.1285 in	1.1298 in	1.1350 in	1.1290 in
FAILURE LOAD	312.4200 lbs	277.2300 lbs	263.8800 lbs	352.9600 lbs
TENSILE STRENGTH	340.21 psi	305.80 psi	292.37 psi	403.89 psi
DENSITY	2.1306 g/cc	2.1816 g/cc	2.1681 g/cc	2.1464 g/cc

AVER TS= 335.57 psi
AVER DENS= 2.1567 g/cc

Table 10

SAMPLE TESTED
GOLD SEAL BENTONITE w 5% KCl Solution
CONFINING PRESSURE = atmospheric

	RUN#1	RUN#2	RUN#3	RUN#4
WT SAMPL (WET)	12.4584 gr	11.6449 gr	12.2165 gr	11.8998 gr
WT SAMPL+PAPER(DRY)	11.9760 gr	11.5818 gr	11.8030 gr	12.0397 gr
WT PAPER (DRY)	1.0319 gr	1.4121 gr	1.0329 gr	1.4556 gr
WT SAMPLE	10.9441 gr	10.1697 gr	10.7701 gr	10.5841 gr
WT H20	1.5143 gr	1.4752 gr	1.4464 gr	1.3157 gr
% WATER	12.15	12.67	11.84	11.06
AVER THICKNESS	0.3420 in	0.3173 in	0.3323 in	0.3195 in
AVER DIAMETER	1.1288 in	1.1380 in	1.1280 in	1.1288 in
FAILURE LOAD	298.4700 lbs	271.7700 lbs	266.9000 lbs	303.3200 lbs
TENSILE STRENGTH	354.38 psi	344.99 psi	326.38 psi	385.52 psi
DENSITY	2.2213 g/cc	2.2019 g/cc	2.2449 g/cc	2.2713 g/cc

AVER TS= 352.82 psi
AVER DENS= 2.2349 g/cc

Table 11

SAMPLE TESTED
GOLD SEAL BENTONITE w/ 10% KCl Solution
CONFINING PRESSURE = atmospheric

	RUN#1	RUN#2	RUN#3	RUN#4
WT SAMPL WET	12.7739 gr	11.5091 gr	12.4452 gr	10.6128 gr
WT SAMPL+PAPER(DRY)	12.8588 gr	11.8128 gr	12.0515 gr	11.0959 gr
WT PAPER (DRY)	1.4033 gr	1.4600 gr	1.0117 gr	1.5253 gr
WT SAMPLE	11.4555 gr	10.3528 gr	11.0398 gr	9.5706 gr
WT H2O	1.3184 gr	1.1563 gr	1.4054 gr	1.0422 gr
% WATER	10.32	11.17	11.29	9.82
AVER THICKNESS	0.3480 in	0.3065 in	0.3428 in	0.2825 in
AVER DIAMETER	1.1080 in	1.1325 in	1.1088 in	1.1370 in
FAILURE LOAD	269.95 lbs	197.74 lbs	183.20 lbs	172.89 lbs
TENSILE STRENGTH	320.91 psi	261.12 psi	220.92 psi	246.72 psi
DENSITY	2.3231 g/cc	2.2748 g/cc	2.2944 g/cc	2.2579 g/cc

AVER TS= 262.42 psi
AVER DENS= 2.2875 g/cc

Table 12

SAMPLE TESTED
PHILLIPS ANDREWS COUNTY dry
CONFINING PRESSURE = atmospheric

	RUN#1	RUN#2	RUN#3	RUN#4
WT APP+SAMPLE	615.1497 gr	620.2013 gr	539.7834 gr	620.1958 gr
WT APP	603.1515 gr	608.1992 gr	527.7770 gr	608.1867 gr
WT SAMPLE	11.9982 gr	12.0021 gr	12.0064 gr	12.0091 gr
AVER THICKNESS	0.3260 in	0.3240 in	0.3210 in	0.3188 in
AVER DIAMETER	1.1330 in	1.1270 in	1.1210 in	1.1250 in
FAILURE LOAD	342.7500 lbs	260.8500 lbs	317.2700 lbs	261.9900 lbs
TENSILE STRENGTH	425.35 psi	327.44 psi	404.14 psi	334.83 psi
DENSITY	2.2277 g/cc	2.2661 g/cc	2.3126 g/cc	2.3126 g/cc

AVER TS 372.94 psi
AVER DENS 2.2797 g/cc

Table 13

SAMPLE TESTED
PHILLIPS ANDREWS COUNTY w Demin H2O
CONFINING PRESSURE = atmospheric

	RUN#1	RUN#2	RUN#3	RUN#4
WT SAMPL WET	11.9181 gr	12.1015 gr	12.3968 gr	11.7980 gr
WT SAMPL+PAPER(DRY)	12.5281 gr	12.8893 gr	12.8363 gr	12.4268 gr
WT PAPER (DRY)	1.4627 gr	1.5266 gr	1.5179 gr	1.4091 gr
WT SAMPLE	11.0654 gr	11.3627 gr	11.3184 gr	11.0177 gr
WT H2O	0.8527 gr	0.7388 gr	1.0784 gr	0.7803 gr
% WATER	7.15	6.11	8.70	
AVER THICKNESS	0.3115 in	0.3123 in	0.3225 in	0.3012 in
AVER DIAMETER	1.1370 in	1.1260 in	1.1370 in	1.1110 in
FAILURE LOAD	209.2900 lbs	237.8000 lbs	229.3000 lbs	243.7900 lbs
TENSILE STRENGTH	270.86 psi	309.97 psi	286.63 psi	333.93 psi
DENSITY	2.2995 g/cc	2.3746 g/cc	2.3103 g/cc	2.4657 g/cc

AVER TS 300.35 psi
AVER DENS 2.3625 g/cc

Table 14

SAMPLE TESTED
PHILLIPS ANDREWS COUNTY w 5% KCL Solution
CONFINING PRESSURE = atmospheric

	RUN#1	RUN#2	RUN#3	RUN#4
WT SAMPL WET	11.2641 gr	10.7596 gr	12.2906 gr	12.1038 gr
WT SAMPL+PAPER(DRY)	11.3980 gr	11.1235 gr	12.3196 gr	11.9383 gr
WT PAPER (DRY)	0.8569 gr	1.0479 gr	0.8583 gr	0.7816 gr
WT SAMPLE	10.5411 gr	10.0756 gr	11.4613 gr	11.1567 gr
WT H2O	0.7230 gr	0.6840 gr	0.8293 gr	0.9471 gr
% WATER	6.42	6.36	6.75	7.82
AVER THICKNESS	0.2800 in	0.2683 in	0.3168 in	0.3075 in
AVER DIAMETER	1.1390 in	1.1380 in	1.1173 in	1.1300 in
FAILURE LOAD	251.1500 lbs	212.9300 lbs	265.1000 lbs	278.4500 lbs
TENSILE STRENGTH	360.96 psi	319.66 psi	343.30 psi	367.31 psi
DENSITY	2.4093 g/cc	2.4060 g/cc	2.4147 g/cc	2.3951 g/cc

AVER TS 347.81 psi
AVER DENS 2.4063 g/cc

Table 15

SAMPLE TESTED
PHILLIPS ANDREWS COUNTY w 10% KCL
CONFINING PRESSURE = atmospheric

	RUN#1	RUN#2	RUN#3	RUN#4
WT SAMPL WET	11.6958 gr	12.3632 gr	10.1090 gr	11.7791 gr
WT SAMPL+PAPER(DRY)	12.6418 gr	13.1322 gr	10.9085 gr	12.6416 gr
WT PAPER (DRY)	1.5268 gr	1.4488 gr	1.4030 gr	1.4994 gr
WT SAMPLE	11.1150 gr	11.6834 gr	9.5055 gr	11.1422 gr
WT H2O	0.5808 gr	0.6798 gr	0.6035 gr	0.6369 gr
% WATER	4.97	5.50	5.97	5.41
AVER THICKNESS	0.2828 in	0.3060 in	0.2460 in	0.2883 in
AVER DIAMETER	1.1370 in	1.1293 in	1.1303 in	1.1308 in
FORCE AT FAILURE	257.8200 lbs	246.2900 lbs	220.8200 lbs	281.4800 lbs
TENSILE STRENGTH	367.59 psi	326.70 psi	364.03 psi	395.76 psi
DENSITY	2.4861 g/cc	2.4617 g/cc	2.4994 g/cc	2.4826 g/cc

AVER TS 363.52 psi
AVER DENS 2.4824 g/cc

Table 16

SAMPLE TESTED
PHILLIPS EKO FISK
CONFINING PRESSURE = atmospheric

	RUN#1	RUN#2	RUN#3	RUN#4
WT APP+SAMPLE	615.1445 gr	620.2153 gr	540.6163 gr	615.1257 gr
WT APP	603.1476 gr	608.2047 gr	528.6141 gr	603.1287 gr
WT SAMPLE	11.9969 gr	12.0106 gr	12.0022 gr	11.9970 gr
AVER THICKNESS	0.3393 in	0.345 in	0.328 in	0.348 in
AVER DIAMETER	1.1133 in	1.129 in	1.123 in	1.133 in
FAILURE LOAD	330.52 lbs	360.84 lbs	321.42 lbs	314.85 lbs
TENSILE STRENGTH	401.07 psi	424.64 psi	399.61 psi	366.02 psi
DENSITY	2.2161 g/cc	2.1217 g/cc	2.2520 g/cc	2.0862 g/cc

AVER TS 397.83 psi
AVER DENS 2.1690 g/cc

Table 17

SAMPLE TESTED
PHILLIPS EKOFISK w 10% KCL
CONFINING PRESSURE = atmospheric

	RUN#1	RUN#2	RUN#3	RUN#4
WT SAMPL WET	10.3312 gr	9.6838 gr	12.0326 gr	10.7447 gr
WT SAMPL+PAPER(DRY)	10.8631 gr	10.4184 gr	12.3359 gr	10.9051 gr
WT PAPER (DRY)	1.4595 gr	1.5288 gr	1.4008 gr	1.0269 gr
WT SAMPLE	9.4036 gr	8.8896 gr	10.9351 gr	9.8782 gr
WT H2O	0.9276 gr	0.7942 gr	1.0975 gr	0.8665 gr
% WATER	8.98	8.20	9.12	8.06
AVER THICKNESS	0.2652 in	0.2638 in	0.3130 in	0.2828 in
AVER DIAMETER	1.1237 in	1.1108 in	1.1275 in	1.1303 in
FAILURE LOAD	257.7400 lbs	207.4700 lbs	260.8500 lbs	272.9900 lbs
TENSILE STRENGTH	396.40 psi	324.50 psi	338.80 psi	391.46 psi
DENSITY	2.3971 g/cc	2.3116 g/cc	2.3496 g/cc	2.3107 g/cc

AVER TS 362.79 psi
AVER DENS 2.3422 g/cc

Table 18

SAMPLE TESTED
TEXACO MISSISSIPPI CANYON   dry
CONFINING PRESSURE = atmospheric

	RUN#1	RUN#2	RUN#3	RUN#4
WT APP+SAMPLE	540.3727 gr	537.2101 gr	537.1728 gr	537.1728 gr
WT APP	528.3728 gr	525.2113 gr	525.1696 gr	525.1696 gr
WT SAMPLE	11.9999 gr	11.9988 gr	12.0032 gr	12.0032 gr
				11.2841
AVER THICKNESS	0.3440 in	0.3420 in	0.3480 in	0.3330 in
AVER DIAMETER	1.1310 in	1.1410 in	1.1370 in	1.1347 in
FAILURE LOAD	360.84 lbs	272.38 lbs	368.84 lbs	305.75 lbs
TENSILE STRENGTH	425.12 psi	319.95 psi	427.28 psi	370.90 psi
DENSITY	2.1189 g/cc	2.0939 g/cc	2.0730 g/cc	2.0449 g/cc

AVER TS   385.81 psi
AVER DENS   2.0827 g/cc

Table 19

SAMPLE TESTED
TEXACO MISSISSIPPI CANYON   w Demin H2O
CONFINING PRESSURE = atmospheric

	RUN#1	RUN#2	RUN#3	RUN#4
WT SAMPL WET	9.7931 gr	11.6827 gr	9.0432 gr	10.7081 gr
WT SAMPL+PAPER(DRY)	10.2963 gr	12.3570 gr	9.3048 gr	11.0335 gr
WT PAPER (DRY)	1.256 gr	1.7564 gr	1.0098 gr	1.0111 gr
WT SAMPLE(DRY)	9.0403 gr	10.6006 gr	8.2950 gr	10.0224 gr
WT H2O	0.7528 gr	1.0821 gr	0.7482 gr	0.6857 gr
% WATER	7.69	9.26	8.27	6.40
AVER THICKNESS	0.2610 in	0.2980 in	0.2330 in	0.2720 in
AVER DIAMETER	1.1263 in	1.1300 in	1.1347 in	1.1307 in
FAILURE LOAD	305.75 lbs	305.75 lbs	243.26 lbs	297.77 lbs
TENSILE STRENGTH	476.75 psi	416.18 psi	421.74 psi	443.79 psi
DENSITY	2.2982 g/cc	2.3855 g/cc	2.3421 g/cc	2.3925 g/cc

AVER TS   439.62 psi
AVER DENS   2.3546 g/cc

Table 20

SAMPLE TESTED
TEXACO MISSISSIPPI CANYON w 5% KCL
CONFINING PRESSURE = atmospheric

	RUN#1	RUN#2	RUN#3	RUN#4
WT SAMPL WET	11.5889 gr	9.8270 gr	10.5857 gr	11.4264 gr
WT SAMPL+PAPER(DRY)	11.7226 gr	10.1568 gr	11.2326 gr	11.9524 gr
WT PAPER (DRY)	1.0282 gr	1.0881 gr	1.4110 gr	1.3749 gr
WT SAMPLE	10.6944 gr	9.0687 gr	9.8216 gr	10.5775 gr
WT H20	0.8945 gr	0.7583 gr	0.7641 gr	0.8489 gr
% WATER	7.72	7.72	7.22	7.43
AVER THICKNESS	0.3033 in	0.2540 in	0.2750 in	0.2955 in
AVER DIAMETER	1.1310 in	1.1400 in	1.3080 in	1.1200 in
FAILURE LOAD	363.37 lbs	299.07 lbs	343.96 lbs	312.33 lbs
TENSILE STRENGTH	485.54 psi	473.42 psi	438.31 psi	432.57 psi
DENSITY	2.3209 g/cc	2.3131 g/cc	1.7482 g/cc	2.3951 g/cc

AVER TS 457.46 psi
AVER DENS 2.1943 g/cc

Table 21

SAMPLE TESTED
TEXACO MISSISSIPPI CANYON w 10% KCL
CONFINING PRESSURE = atmospheric

	RUN#1	RUN#2	RUN#3	RUN#4
WT SAMPL WET	12.2304 gr	10.3666 gr	9.6391 gr	10.6497 gr
WT SAMPL+PAPER(DRY)	12.0151 gr	11.1448 gr	10.4315 gr	11.5953 gr
WT PAPER (DRY)	1.5236 gr	1.4466 gr	1.4016 gr	1.5272 gr
WT SAMPLE	10.4915 gr	9.6982 gr	9.0299 gr	10.0681 gr
WT H2O	1.7389 gr	0.6684 gr	0.6092 gr	0.5816 gr
% WATER	14.22	6.45	6.32	5.46
AVER THICKNESS	0.2905 in	0.2643 in	0.2528 in	0.2763 in
AVER DIAMETER	1.1315 in	1.1393 in	1.1313 in	1.1395 in
FORCE AT FAILURE	319.70 lbs	298.47 lbs	266.30 lbs	333.65 lbs
TENSILE STRENGTH	445.82 psi	454.34 psi	426.80 psi	485.75 psi
DENSITY	2.5550 g/cc	2.3479 g/cc	2.3148 g/cc	2.3064 g/cc

AVER TS 453.18 psi
AVER DENS 2.3810 g/cc

Table 22

SAMPLE TESTED
PIERRE TEXACO dry
CONFINING PRESSURE = atmospheric

	RUN#1	RUN#2	RUN#3	RUN#4
WT APP+SAMPLE	615.1237 gr	620.1942 gr	615.1156 gr	620.1857 gr
WT APP	603.1260 gr	608.1965 gr	603.1184 gr	608.1850 gr
WT SAMPLE	11.9977 gr	11.9977 gr	11.9972 gr	12.0007 gr
AVER THICKNESS	0.3695 in	0.3783 in	0.3737 in	0.3700 in
AVER DIAMETER	1.1370 in	1.1300 in	1.1370 in	1.1335 in
FAILURE LOAD	314.75 lbs	340.22 lbs	369.94 lbs	376.00 lbs
TENSILE STRENGTH	343.40 psi	364.80 psi	399.08 psi	410.94 psi
DENSITY	1.9515 g/cc	1.9298 g/cc	1.9295 g/cc	1.9614 g/cc

AVER TS 379.56 psi
AVER DENS 1.9431 g/cc

Table 23

SAMPLE TESTED
PIERRE TEXACO w Demin H20
CONFINING PRESSURE = atmospheric

	RUN#1	RUN#2	RUN#3	RUN#4
WT SAMPL WET	12.9425 gr	12.8790 gr	12.2400 gr	12.9737 gr
WT SAMPL+PAPER(DRY)	11.9592 gr	12.1123 gr	11.5251 gr	11.9680 gr
WT PAPER (DRY)	0.9867 gr	0.9118 gr	0.9795 gr	0.9178 gr
WT SAMPLE	10.9725 gr	11.2005 gr	10.5456 gr	11.0502 gr
WT H20	1.97 gr	1.6785 gr	1.6944 gr	1.9235 gr
% WATER	15.22	13.03	13.84	14.83
AVER THICKNESS	0.3728 in	0.3603 in	0.3440 in	0.3688 in
AVER DIAMETER	1.1298 in	1.1265 in	1.1355 in	1.1268 in
FAILURE LOAD	311.21 lbs	252.36 lbs	220.82 lbs	281.48 lbs
TENSILE STRENGTH	338.68 psi	285.00 psi	259.12 psi	310.47 psi
DENSITY	2.1132 g/cc	2.1886 g/cc	2.1442 g/cc	2.1527 g/cc

AVER TS 298.32 psi
AVER DENS 2.1497 g/cc

Table 24

SAMPLE TESTED
PIERRE TEXACO w 5% KCL Solution
CONFINING PRESSURE = atmospheric

	RUN#1	RUN#2	RUN#3	RUN#4
WT SAMPL WET	11.9164 gr	12.0478 gr	10.8199 gr	12.2727 gr
WT SAMPL+PAPER(DRY)	11.4716 gr	11.7531 gr	11.0581 gr	12.2661 gr
WT PAPER (DRY)	0.7187 gr	1.0317 gr	1.4461 gr	1.4048 gr
WT SAMPLE	10.7529 gr	10.7214 gr	9.6120 gr	10.8613 gr
WT H2O	1.1635 gr	1.3264 gr	1.2079 gr	1.4114 gr
% WATER	9.76	11.01	11.16	11.50
AVER THICKNESS	0.3230 in	0.3350 in	0.2990 in	0.3370 in
AVER DIAMETER	1.1300 in	1.1200 in	1.1210 in	1.1290 in
FAILURE LOAD	365.19 LBS	405.84 lbs	312.93 lbs	312.93 lbs
TENSILE STRENGTH	458.62 psi	495.80 psi	427.94 psi	377.00 psi
DENSITY	2.2449 g/cc	2.2276 g/cc	2.2374 g/cc	2.2199 g/cc

AVER TS 439.84 psi
AVER DENS 2.2324 g/cc

Table 25

SAMPLE TESTED
PIERRE TEXACO w 10% KCL Solution
CONFINING PRESSURE = atmospheric

	RUN#1	RUN#2	RUN#3	RUN#4
WT SAMPL WET	11.9283 gr	12.4957 gr	12.2621 gr	12.5857 gr
WT SAMPL+PAPER(DRY)	12.4845 gr	12.8256 gr	12.9262 gr	12.6692 gr
WT PAPER (DRY)	1.5222 gr	1.4513 gr	1.5382 gr	1.5289 gr
WT SAMPLE	10.9623 gr	11.3743 gr	11.3880 gr	11.1403 gr
WT H2O	0.9660 gr	1.1214 gr	0.8741 gr	1.4454 gr
% WATER	8.10	8.97	7.13	11.48
AVER THICKNESS	0.3143 in	0.3343 in	0.3243 in	0.3420 in
AVER DIAMETER	1.1383 in	1.1318 in	1.1388 in	1.1313 in
FORCE AT FAILURE	335.47 lbs	469.54 lbs	382.22 lbs	401.59 lbs
TENSILE STRENGTH	429.80 psi	568.83 psi	474.39 psi	475.76 psi
DENSITY	2.2758 g/cc	2.2672 g/cc	2.2653 g/cc	2.2341 g/cc

AVER TS 487.19 psi
AVER DENS 2.2606 g/cc

Table 26

SAMPLE TESTED
TEXACO ATOKA RECONSTITUTED dry
CONFINING PRESSURE = atmsopheric

	RUN#1	RUN#2	RUN#3	RUN#4
WT APP+SAMPLE	623.2389 gr	629.2214 gr	619.7784 gr	o29.9789 gr
WT APP	611.2584 gr	617.1237 gr	607.7749 gr	617.9654 gr
WT SAMPLE	11.4984 gr	11.7446 gr	11.6451 gr	11.8132 gr
AVER THICKNESS	0.3367 in	0.3360 in	0.3285 in	0.3367 in
AVER DIAMETER	1.1223 in	1.1135 in	1.1290 in	1.1140 in
FAILURE LOAD	145.55 lbs	159.49 lbs	189.21 lbs	225.60 lbs
TENSILE STRENGTH	176.56 psi	195.40 psi	233.85 psi	275.69 psi
DENSITY	2.1068 g/cc	2.1904 g/cc	2.1609 g/cc	2.1967 g/cc

AVER TS 220.37 psi
AVER DENS 2.164 g/cc

Table 27

SAMPLE TESTED
TEXACO ATOKA RECONSTITUTED w Demin H2O
CONFINING PRESSURE = atmospheric

	RUN#1	RUN#2	RUN#3	RUN#4
WT SAMPL WET	8.9205 gr	10.3009 gr	11.541 gr	10.0054 gr
WT SAMPL+PAPER(DRY)	9.9168 gr	11.1243 gr	12.2049 gr	10.9244 gr
WT PAPER (DRY)	1.4558 gr	1.466 gr	1.1796 gr	1.5071 gr
WT SAMPLE	8.461 gr	9.6583 gr	11.0253 gr	9.4173 gr
WT H2O	0.4595 gr	0.6426 gr	0.5157 gr	0.5881 gr
% WATER	5.15	6.24	4.47	5.88
AVER THICKNESS	0.2330 in	0.2613 in	0.2913 in	0.2558 in
AVER DIAMETER	1.1333 in	1.1368 in	1.1300 in	1.1208 in
FAILURE LOAD	90.03 lbs	125.58 lbs	151.05 lbs	110.4100 lbs
TENSILE STRENGTH	156.28 psi	193.78 psi	210.34 psi	176.52 psi
DENSITY	2.3161 g/cc	2.3702 g/cc	2.4108 g/cc	2.4193 g/cc

AVER TS 184.23 psi
AVER DENS 2.379 g/cc

Table 28

SAMPLE TESTED
TEXACO ATOKA RECONSTITUTED w 5% KCL
CONFINING PRESSURE = ATMOSPHERIC

	RUN#1	RUN#2	RUN#3	RUN#4
WT SAMPL WET	10.9685 gr	10.7307 gr	11.6499 gr	10.842 gr
WT SAMPL+PAPER(DRY)	11.7342 gr	11.5894 gr	12.2786 gr	11.8267 gr
WT PAPER (DRY)	1.4022 gr	1.4523 gr	1.4586 gr	1.5313 gr
WT SAMPLE	10.332 gr	10.1371 gr	10.82 gr	10.2954 gr
WT H2O	0.6365 gr	0.5936 gr	0.8299 gr	0.5466 gr
% WATER	5.803	5.532	7.124	5.042
AVER THICKNESS	0.2800 in	0.2680 in	0.2923 in	0.2710 in
AVER DIAMETER	1.1315 in	1.1405 in	1.1318 in	1.1388 in
FAILURE LOAD	158.33 lbs	158.94 lbs	198.98 lbs	191.09 lbs
TENSILE STRENGTH	229.07 psi	238.35 psi	275.69 psi	283.81 psi
DENSITY	2.3773 g/cc	2.3917 g/cc	2.4175 g/cc	2.3969 g/cc

AVER TS 256.73 psi
AVER DENS 2.396 g/cc

Table 29

SAMPLE TESTED
TEXACO ATOKA RECONSTITUTED w 10% KCL
CONFINING PRESSURE = ATMOSPHERIC

	RUN#1	RUN#2	RUN#3	RUN#4
WT SAMPL WET	11.1774 gr	11.2159 gr	11.1668 gr	11.391 gr
WT SAMPL+PAPER(DRY)	12.0689 gr	11.6033 gr	12.083 gr	11.7731 gr
WT PAPER (DRY)	1.4482 gr	1.0075 gr	1.4537 gr	1.009 gr
WT SAMPLE	10.6207 gr	10.5958 gr	10.6293 gr	10.7641 gr
WT H20	0.5567 gr	0.6201 gr	0.5375 gr	0.6269 gr
% WATER	4.98	5.53	4.81	5.50
AVER THICKNESS	0.2780 in	0.2823 in	0.2760 in	0.2923 in
AVER DIAMETER	1.1381 in	1.1325 in	1.1398 in	1.1320 in
FAILURE LOAD	212.93 lbs	233.56 lbs	206.26 lbs	180.78 lbs
TENSILE STRENGTH	308.48 psi	334.86 psi	300.53 psi	250.43 psi
DENSITY	2.4118 g/cc	2.4069 g/cc	2.4198 g/cc	2.3629 g/cc

AVER TS 298.58 psi
AVER DENS 2.400 g/cc

Table 30

SAMPLE TESTED
PIERRE TEXACO native w air
CONFINING PRESSURE = atmospheric

	RUN#1	RUN#2	RUN#3
WT SAMPL WET	8.8577 gr	9.1469 gr	7.3961 gr
WT SAMPL+PAPER(DRY)	8.6663 gr	9.1181 gr	7.6287 gr
WT PAPER (DRY)	1.4347 gr	1.4781 gr	1.4162 gr
WT SAMPLE	7.2316 gr	7.6400 gr	6.2125 gr
WT H2O	1.6261 gr	1.5069 gr	1.1836 gr
% WATER	18.36	16.47	16.00
AVER THICKNESS	0.2668 in	0.3650 in	0.2933 in
AVER DIAMETER	0.9823 in	0.9770 in	0.9878 in
FORCE AT FAILURE	220.21 lbs	274.20 LBS	271.77 lbs
TENSILE STRENGTH	385.14 psi	352.45 psi	429.97 psi
DENSITY	2.6733 g/cc	2.0399 g/cc	2.0080 g/cc

AVER TS 389.18 psi
AVER DENS 2.2404 g/cc

Table 31

SAMPLE TESTED
PIERRE TEXACO native w Demin H2O
CONFINING PRESSURE = atmospheric

	RUN#1	RUN#2	RUN#3
WT SAMPL WET	8.1705 gr	9.0214 gr	11.1810 gr
WT SAMPL+PAPER(DRY)	8.4968 gr	9.3797 gr	11.1829 gr
WT PAPER (DRY)	1.4088 gr	1.4498 gr	1.5472 gr
WT SAMPLE	7.0880 gr	7.9299 gr	9.6357 gr
WT H2O	1.0825 gr	1.0915 gr	1.5453 gr
% WATER	13.25	12.10	13.82
AVER THICKNESS	0.2298 in	0.2430 in	0.3235 in
AVER DIAMETER	1.1275 in	1.1355 in	1.1282 in
FORCE AT FAILURE	150.40 lbs	182.50 lbs	242.66 lbs
TENSILE STRENGTH	267.58 psi	304.89 psi	306.49 psi
DENSITY	2.1731 g/cc	2.2372 g/cc	2.1098 g/cc

AVER TS 292.99 psi
AVER DENS 2.1734 g/cc

Table 32

SAMPLE TESTED
PIERRE TEXACO NATIVE w 5% KCL
CONFINING PRESSURE = atmospheric

	RUN#1	RUN#2	RUN#3
WT SAMPL WET	8.5061 gr	7.8107 gr	13.4648 gr
WT SAMPL+PAPER(DRY)	9.0617 gr	8.4583 gr	13.8490 gr
WT PAPER (DRY)	1.5356 gr	1.4528 gr	1.7026 gr
WT SAMPLE	7.5261 gr	7.0055 gr	12.1464 gr
WT H20	0.9800 gr	0.8052 gr	1.3184 gr
% WATER	11.52	10.31	9.79
AVER THICKNESS	0.2327 in	0.2140 in	0.3668 in
AVER DIAMETER	1.1295 in	1.1380 in	1.1375 in
FORCE AT FAILURE	172.84 lbs	192.85 LBS	319.70 lbs
TENSILE STRENGTH	301.42 psi	362.97 psi	351.22 psi
DENSITY	2.2262 g/cc	2.1898 g/cc	2.2043 g/cc

AVER TS 338.54 psi
AVER DENS 2.2068 g/cc

Table 33

SAMPLE TESTED
PIERRE TEXACO NATIVE w 10% KCL
CONFINING PRESSURE = atmospheric

	RUN#1	RUN#2	RUN#3
WT SAMPL WET	10.9863 gr	10.9798 gr	11.2132 gr
WT SAMPL+PAPER(DRY)	11.3128 gr	11.1988 gr	11.3452 gr
WT PAPER (DRY)	1.5135 gr	1.4067 gr	1.5033 gr
WT SAMPLE	9.7993 gr	9.7921 gr	9.8419 gr
WT H2O	1.1870 gr	1.1877 gr	1.3713 gr
% WATER	10.80	10.82	12.23
AVER THICKNESS	0.3030 in	0.3030 in	0.3255 in
AVER DIAMETER	1.1298 in	1.1295 in	1.1113 in
FORCE AT FAILURE	284.40 lbs	308.08 lbs	322.64 lbs
TENSILE STRENGTH	380.82 psi	412.62 psi	408.85 psi
DENSITY	2.2073 g/cc	2.2069 g/cc	2.1675 g/cc

AVER TS 400.76 psi
AVER DENS 2.1939 g/cc

Table 34

SAMPLE TESTED
TEXACO ATOKA NATIVE
CONFINING PRESSURE = atmospheric

	RUN#1	RUN#2	RUN#3
WT SAMPL WET	12.4665 gr	14.2535 gr	10.1246 gr
WT SAMPL WET	10.2735 gr	14.5415 gr	10.1286 gr
WT SAMPL+PAPER(DRY)	11.3382 gr	15.1078 gr	10.7807 gr
WT PAPER (DRY)	1.3823 gr	1.0169 gr	1.0177 gr
WT SAMPLE	9.9559 gr	14.0909 gr	9.763 gr
WT H2O	0.3176 gr	0.4506 gr	0.3656 gr
% WATER	2.55	3.16	3.61
AVER THICKNESS	0.3830 in	0.4470 in	0.3090 in
AVER DIAMETER	0.9885 in	0.9900 in	0.9880 in
FAILURE LOAD	1049.17 lbs	867.2400 lbs	770.2000 lbs
TENSILE STRENGTH	1270.24 psi	898.28 psi	1156.39 psi
DENSITY	2.5882 g/cc	2.5279 g/cc	2.6080 g/cc

AVER TS 1108.30 psi
AVER DENS 2.575 g/cc

Table 35

SAMPLE TESTED
TEXACO ATOKA NATIVE w demin H2O
CONFINING PRESSURE = atmospheric

	RUN#1	RUN#2	RUN#3
WT SAMPL WET	10.1731 gr	11.4943 gr	14.4216 gr
WT SAMPL+PAPER(DRY)	11.2816 gr	12.5252 gr	15.292 gr
WT PAPER (DRY)	1.533 gr	1.4522 gr	1.4109 gr
WT SAMPLE	9.7486 gr	11.073 gr	13.8811 gr
WT H2O	0.4245 gr	0.4213 gr	0.5405 gr
% WATER	4.17	3.67	3.75
AVER THICKNESS	0.2503 in	0.2812 in	0.3480 in
AVER DIAMETER	1.1377 in	1.1347 in	1.1322 in
FAILURE LOAD	109.19 lbs	78.86 lbs	76.4300 lbs
TENSILE STRENGTH	175.79 psi	113.29 psi	88.91 psi
DENSITY	2.4402 g/cc	2.4667 g/cc	2.5119 g/cc

AVER TS 126.00 psi
AVER DENS 2.473 g/cc

Table 36

SAMPLE TESTED
TEXACO ATOKA NATIVE w 5% KCL
CONFINING PRESSURE = atmospheric

	RUN#1	RUN#2	RUN#3
WT SAMPL WET	13.7936 gr	11.789 gr	12.9805 gr
WT SAMPL+PAPER(DRY)	14.7862 gr	12.7003 gr	13.9693 gr
WT PAPER (DRY)	1.4514 gr	1.4522 gr	1.5044 gr
WT SAMPLE	13.3348 gr	11.2481 gr	12.4649 gr
WT H20	0.4588 gr	0.5409 gr	0.5156 gr
% WATER	3.33	4.59	3.97
AVER THICKNESS	0.3373 in	0.2983 in	0.3150 in
AVER DIAMETER	1.1308 in	1.1120 in	1.1308 in
FAILURE LOAD	132.25 lbs	94.03 lbs	112.23 lbs
TENSILE STRENGTH	158.94 psi	129.96 psi	144.43 psi
DENSITY	2.4851 g/cc	2.4837 g/cc	2.5041 g/cc

AVER TS 144.44 psi
AVER DENS 2.491 g/cc

Table 37

SAMPLE TESTED
TEXACO ATOKA NATIVE w 10% KCL
CONFINING PRESSURE = atmospheric

	RUN#1	RUN#2	RUN#3
WT SAMPL WET	11.0075 gr	9.9563 gr	15.8394 gr
WT SAMPL+PAPER(DRY)	12.1032 gr	11.1231 gr	16.8354 gr
WT PAPER (DRY)	1.4248 gr	1.4486 gr	1.4928 gr
WT SAMPLE DRY	10.6784 gr	9.6745 gr	15.3426 gr
WT H2O	0.3291 gr	0.2818 gr	0.4968 gr
% WATER	2.99	2.83	3.14
AVER THICKNESS	0.2723 in	0.2538 in	0.3753 in
AVER DIAMETER	1.1285 in	1.1105 in	1.1363 in
FAILURE LOAD	95.85 lbs	84.32 lbs	74.62 lbs
TENSILE STRENGTH	142.97 psi	137.13 psi	80.20 psi
DENSITY	2.4663 g/cc	2.4716 g/cc	2.5397 g/cc

AVER TS 120.10 psi
AVER DENS 2.493 g/cc

Table 38

SAMPLE TESTED
TEXACO ATOKA NATIVE
CONFINING PRESSURE 1000 psig

	RUN#1	RUN#2	RUN#3
WT SAMPLE	14.0634 gr	23.5211 gr	10.9379 gr
AVER THICKNESS	0.4310 in	0.7173 in	0.3293 in
AVER DIAMETER	0.9910 in	1.0020 in	1.0345 in
FAILURE LOAD	1741.00 lbs	2517.56 lbs	1104.00 lbs
TENSILE STRENGTH	2594.95 psi	2229.94 psi	2063.14 psi
DENSITY	2.5815 g/cc	2.5376 g/cc	2.4115 g/cc

AVER TS 2296.01 psi
AVER DENS 2.510 g/cc

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